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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 1

Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.
September 17, 1913.

MEDICAL MILK COMMISSIONS AND CERTIFIED MILK.[1]

By Ernest Kelley,
In Charge of Market Milk Investigations.

THE WORK OF MILK COMMISSIONS.

The organization of milk commissions in this country was an important step toward the improvement of the quality of milk. While the number of commissions is very limited and the milk produced under their supervision amounts to only a small proportion of the milk annually consumed, the great value of certified milk to invalids and its influence in reducing the mortality among infants and children are beyond estimation. Further, the work of milk commissions has had no little influence in improving the general milk supply of cities where such commissions exist, by setting a higher standard of quality and by creating public sentiment in favor of pure milk.

THE FIRST COMMISSION: ITS ORGANIZATION AND OBJECTS.

The beginning of this movement dates back to 1889, when the Medical Society of New Jersey made an effort to improve the milk production in that State. A committee was appointed to make an investigation of the milk supply as far as it affected the public health. After two years' work this committee submitted a report condemning many of the methods employed in the production and handling of milk and advising an appeal to the State for a strict scientific supervision of all the dairies within its limits. The appeal was made, but failed. While the need was admitted, the authorities pleaded lack of funds for making the changes suggested.

This effort having met with defeat, another line of work was resorted to. The chairman, a Newark physician, presented a plan in 1892 to the Practitioners' Club of that city whereby physicians might themselves supervise the production of milk and thus be perfectly sure of its purity. The requirements for the production of certified

[1] An extensive revision of Bulletin 104, Bureau of Animal Industry, Medical Milk Commissions and the Production of Certified Milk in the United States, by C. B. Lane, 1908.

milk were given with the utmost detail. It was recommended that a milk commission be formed by physicians who should certify to the milk over their names provided the requirements were fulfilled. This plan was indorsed by the Practitioners' Club, and a search was begun for a dairy with equipment suited to such rigid regulations. A dairy was found which had already set such a high standard that the methods used could readily be accommodated to the requirements of the medical commission.

Having secured a dairyman who was ready to bind himself by contract to conduct his dairy in accordance with the requirements, physicians from Newark, Orange, and Montclair were chosen to make up the first milk commission, which was organized April 13, 1893, and the production of what is known as "certified milk" was begun. This commission was named "The Medical Milk Commission of Essex County, New Jersey." Since this was organized about 65 others have been or are now being formed in various cities on a similar plan. A description of the first will therefore serve to give a general idea of milk commissions and their work.

OBJECTS OF THE COMMISSION.

The objects and requirements of the commission were stated as follows:

> The objects of this commission are to establish correct clinical standards of purity for cow's milk; to become responsible for a periodical inspection of the dairies under its patronage; provide for chemical and bacteriological examinations of the product, and the frequent scrutiny of the stock by competent veterinarians; to promote only professional and public interests.
>
> The following are three general requirements or standards for the milk: (1) An absence of large numbers of microorganisms, and the entire freedom of the milk from pathogenic varieties; (2) unvarying resistance to early fermentative changes in the milk, so that it may be kept under ordinary conditions without extraordinary care; (3) a constant nutritive value of known chemical composition, and a uniform relation between the percentage of fats, proteids, and carbohydrates.

THREEFOLD EXAMINATION BY EXPERTS.

A chemist and a bacteriologist examine samples of the milk, which they obtain themselves, twice each month, and report their findings to the commission. A veterinarian examines the cows twice a month and makes report. Representatives of the commission in person make a monthly inspection of the dairy and report to the others.

The veterinarian must show the milch cows to be in perfect health. The chemist must show the milk to contain the required amount of solids and to be free from all foreign matter. The bacteriologist must show the absence of all disease-producing bacteria and a minimum of bacteria of all sorts. Only in case all these reports are satisfactory does the commission certify to the milk.

ORIGIN AND MEANING OF THE TERM "CERTIFIED MILK."

The term "certified milk" originated with the member of the commission who formulated the plan. At the instance of the commission the word "certified" was registered by Mr. Francisco in the United States Patent Office on October 16, 1904, under registry No. 25368, the object being to protect it from being degraded by dairymen not under contract with a medical commission. It was distinctly understood, however, that the use of the term should be allowed without question when employed by medical milk commissions organized to influence dairy work for clinical purposes.

Dr. Henry L. Coit, of Newark, N. J., who has been called "the father of certified milk," gives the following definition[1] of certified milk:

> Milk from a lower animal which has been certified by a medical milk commission appointed by a medical society, which certification is the monthly authorization for the commercial use of the term and which certificate is based upon the commission's investigation relative to the production of the milk showing that it conforms to the standards of quality and purity for certified milk and the methods and regulations for the production of certified milk, which standards of quality consist of a fresh milk, unchanged by either heat or cold, less than 24 hours old when sold, and which contains not less than 12 per cent of total solids, with not less than 3.5 nor more than 5.5 per cent of fat, to which have not been added any other food principle, chemical substance, or preservative, which standards of purity for the milk consist of the lowest possible bacterial and dust-dropping content consistent with the highest possible practice of dairy hygiene, provided that the average numerical contamination is not above an average weekly count of 10,000 bacteria per cubic centimeter, and from which milk every known method has been employed to exclude pathogenic microorganisms, and which standards of purity are safeguarded by a medical guaranty of the health and personal hygiene of every employee handling the milk and by a veterinary guaranty that the milk herd will not be a carrier of any disease to those using the milk for food; which methods and regulations for the production of certified milk are carried on in conformity with those adopted by the American Association of Medical Milk Commissions and are changed from time to time as the action of this association modifies the technique for the attainment of the standards of quality and purity for certified milk growing out of improved methods and regulations for its production.

THE CONTROL OF DAIRIES.

Some commissions—particularly such as have under their supervision only one dairyman who both produces and distributes certified milk—enter into a binding contract with the dairymen. This contract contains a more or less complete and detailed statement of the conditions under which certified milk must be produced and marketed; specifies standards for composition and bacterial content of

[1] This definition is modified somewhat in view of the fact that at the sixth meeting of the American Association of Medical Milk Commissions changes were made in the chemical standards outlined by Dr. Coit.

the milk; provides for inspection of premises, examination of cows, and collection and analysis of milk samples; and includes provisions under which the contract may be terminated by either party entering into it.

Many commissions prefer not to have any contract with their producers and claim that it is superfluous and unnecessary. The producers understand well that if their milk does not come up to the requirements they can not sell it. However, in cases where there are contracts, commissions are not at all hasty in severing relations with a producer when his milk falls below requirements, but make more frequent inspections and lend every effort at such inspections to help the dairyman out of his trouble. In this way when a producer does have trouble he often writes to know when the commission can send a representative to help him out of his difficulty. The efforts of such commissions are therefore to help and cooperate closely with the producer. Some commissions feel safer in the work without a lengthy binding contract. This plan allows a certain latitude for meeting conditions as they arise, and the latter vary greatly at different farms, even though the dairymen all produce milk well within the requirements and standards.

REQUIREMENTS AND STANDARDS.

There has been in the past considerable diversity as to the requirements of the various commissions concerning the production of certified milk. In the spring of 1912 a report was received from 58 milk commissions as to the standards which they had set for both chemical composition and bacterial content.

The requirements for fat range from 3.5 up to 5 per cent, while the standards for total solids range from 12 to 14 per cent. By far the greatest number of commissions required that the bacterial count be kept below 10,000 per cubic centimeter, one of the commissions requiring a count under 5,000 in the wintertime. One commission allowed 15,000, one 20,000, and three 30,000 bacteria per cubic centimeter. It has been generally recognized, however, by those connected with certified-milk work that a standard of 10,000 bacteria per cubic centimeter is that which is usually associated with certified milk.

In order to make the requirements more specific and to unify the work of the various milk commissions, the American Association of Medical Milk Commissions appointed a committee to draw up tentative standards which should be adopted by the association for the production and distribution of certified milk. The report of this committee was read and accepted at the meeting of the association held in Louisville, Ky., May 1, 1912, and the provisions of this report are looked upon as standard regulations for this product. These rules are reprinted in the appendix of this bulletin.

METHODS AND WORK OF THE VARIOUS MILK COMMISSIONS.

NUMBER OF COMMISSIONS AND WHEN ORGANIZED.

As previously stated, the first milk commission was organized April 13, 1893. An effort has been made to get correct data as to when subsequent commissions were organized, but this has proved an exceedingly difficult thing to do. Several commissions have given two different dates of organization, which is rather confusing in compiling statistics. This is probably due to the fact that many commissions were in existence and then for some reason or other became inactive for one or more years and were afterwards reorganized and carried on the original work. Fifty-four commissions reported the dates of their organization, and from their answers the following table has been arranged:

Year of organization.	Commissions organized.	Year of organization.	Commissions organized.
1893	1	1905	2
1896	1	1906	5
1899	1	1907	6
1900	1	1908	14
1901	1	1909	7
1902	3	1910	6
1903	1	1911	2
1904	2	1912	1

The most rapid increase is seen to have taken place from 1906 to 1908, and since that time the increase has somewhat fallen off. This falling off in the number of commissions organized is probably explained by the fact that the field is being better covered so that new commissions are less needed than formerly.

Not only has this movement spread in this country, but two or three commissions have been formed in Canada which conform to the same standards as those in the United States.

In order to obtain information as to the medical milk commissions a large number of circulars were sent out to the various commissions in the spring of 1912. Replies were received from about 65 commissions, and it was found that quite a large number of these had become inactive either through lack of demand for certified milk or because of inability to find dairymen who would submit to the regulations of the commission.

NUMBER OF CERTIFIED DAIRIES AND QUANTITY OF MILK PRODUCED.

The number of dairies producing milk for any one commission varies from 1 to 20. Several commissions were found to be still in

existence and to have a full complement of officers, but not certifying any milk at the time of reporting. The following table shows the number of dairies certified by each commission:

Dairies certified.	Commissions.	Dairies certified.	Commissions.
None	20	5	3
1	19	6	1
2	10	10	1
3	4	12	1
4	3	20	1

Out of 63 commissions reporting as above, 20 had discontinued the certification of milk. The smallest amount certified by any one commission is 75 to 100 quarts a day, while the greatest amount which is passed upon by a single commission is 10,752 quarts a day. A few commissions certify cream as well as milk. Ninety-two certified dairies answered the question blanks sent out, and they report the total quantity of milk produced as 16,633 gallons a day. As there are about 125 certified dairies in all, it seems probable that the total production reaches 25,000 gallons.

The 63 commissions answering the letter reported the certification of 126 dairies. A former investigation (Bureau of Animal Industry Bulletin 104) showed that on January 1, 1907, there were only about 6,000 gallons a day of certified milk produced; so that in five years there has been an increase in the production of certified milk of about 300 per cent.

INSPECTED MILK.

Several of the medical milk commissions are supervising the production of a special grade of milk which is called "inspected milk." This milk does not conform to all the requirements for certified milk, but is still of a high quality and much safer than the ordinary market milk of most cities. It is usually demanded that the cows kept for the production of this milk be free from tuberculosis and that the bacterial count shall be under 100,000 to the cubic centimeter. This milk sells for a less price than does certified milk, and is therefore within the reach of a larger class of consumers. One commission reports that it is inspecting 9 dairies in addition to those certified. The total number of "inspected" dairies reported was 20. The inspection of dairies seems to serve a double purpose, in that it not only puts a clean milk, which is produced under medical supervision, in the hands of the consumer at a reasonable price, but it also serves as a school for dairymen who may contemplate at some future time the production of certified milk.

INSPECTION OF DAIRY AND PRODUCT.

The answers from the various commissions relative to inspections show considerable variation. In some instances the inspections are made by members of the commission and in others paid inspectors are employed to do the work. As a rule, inspections of the dairy are made monthly by either a veterinarian or a member of the commission, or both, and in some instances inspections are made every two weeks. The tuberculin test is usually applied annually, but in some cases this is done every six months. Chemical and bacteriological examinations range all the way from once a week to once in two months; in most instances, however, it is the practice to make tests every two weeks or oftener.

HEALTH OF EMPLOYEES.

The employees in certified-milk plants are required to be clean in habits and appearance and are not admitted to the stables or dairy if not in good health. Some commissions require that employees be regularly examined by a physician and given certificates of health. In some certified-milk plants attendants when ill are cared for in a building specially set apart for the purpose.

PRECAUTIONS TO PREVENT SPREAD OF CONTAGIOUS DISEASES.

Where a large milk business is conducted and several thousand customers are served daily, there is danger that some contagious disease may be brought into the dairy in some of the bottles. To avoid this, in some instances a wagon makes a special trip to collect bottles from any house where a contagious disease is known to exist. These bottles are thoroughly boiled in a special room before they come to the dairy proper. They are then subjected to the same cleansing process as all the others.

SOME GENERAL CONSIDERATIONS.

IS THE DEMAND FOR CERTIFIED MILK INCREASING?

Although there has been a remarkable increase in the quantity of certified milk produced between 1907 and 1912, it must be admitted that the demand is not as great as might be expected. In nearly all localities it is a hard fight for the milk commissions to educate the consumers to the consumption of certified milk. There are two main reasons for this. First, it has been found that there is a general apathy among consumers as to the purity of their milk supply. This would hold good as well with certified as with market milk. Another reason is that the price of certified milk is considerably higher than that of market milk, and it is hard to get people to pay the extra cost. Reports were received from 45 commissions as to the

demand for certified milk. Three of these were indefinite. Only 10 out of this number reported that the demand was increasing rapidly; 1 more stated that the demand was fair, 2 that the demand was increasing steadily, 2 that there was a moderate demand, and 4 that the increase was gradual. This gives a total of 19 commissions that found that the demand was increasing in a satisfactory manner. The other 23 answers were divided as follows: Not a rapid increase, 12; very slow, 1; slight increase, 2; slow increase, 7; limited, 1.

It appears from these answers and from the results tabulated that while certified milk is increasing its sphere of influence, the increase is very slow, and at the present time only about one-half of 1 per cent of the total milk supply of this country is certified. One commission made the report that the demand was fairly good, but no dairyman was willing to supply it. Another commission accounted for the slow increase in the demand for certified milk by saying that the use of certified milk was limited because of the superior quality of the market milk in the city where the commission was located.

PRICES OF CERTIFIED MILK COMPARED WITH THOSE OF MARKET MILK.

The prices of certified milk to the consumer vary in different cities from 10 to 20 cents a quart, the average price for all cities being about 14.2 cents. The price of ordinary market milk in the same cities varies from 5 to 12 cents a quart and averages about 7.8 cents. Certified milk therefore sells for an average of 6.4 cents a quart more than market milk. As a rule, where the price of market milk is low, the price of certified milk is also comparatively low, although this does not hold true in all cases.

It was found in 1907 that the average price of certified milk was $12\frac{1}{4}$ cents a quart, and the average price of market milk was $7\frac{1}{4}$ cents a quart. It will be seen from the foregoing figures that while the average price of market milk has increased only about 0.6 of a cent a quart, the average price of certified milk has increased about 2 cents a quart.

THE INFLUENCE OF CERTIFIED MILK.

While certified milk is in a class by itself and does not enter into competition with ordinary grades of market milk, it has much educational value in cities where it is used. There is no doubt that the advertising of certified milk does much to inform consumers that clean milk costs more than dirty milk and that a cheap milk is apt to be dangerous.

The influence of certified milk on dairymen in general is a little more complex. Certified dairies have certainly shown how to produce the finest grade of milk and have served as models along this

line. An unfortunate feature has been that many of them have been operated at a financial loss, and this has had a demoralizing effect upon many dairymen, who have been led to believe that the production of clean milk necessitates the outlay of large sums of money in expensive equipment.

SO-CALLED CERTIFIED MILK NOT CONTROLLED BY MILK COMMISSIONS.

There are a few dairymen who sell their product under the name of certified milk who have no connection with the milk commissions. These, in some cases, certify to their own product, and in others samples are sent to a State experiment station or to some local chemist or bacteriologist for examination. Some dairymen in this class supply a very creditable product. There are others whose milk is of only ordinary quality. Here, again, the samples for analysis are usually taken by the dairyman himself from milk fresh from the cow and immediately iced and sent to the analyst. The analyst reports his results and the dairyman uses them to advertise his product. This can not be looked upon as anything but a deception, as the consumer is given to understand that this is the analysis of the milk as it is delivered to him daily. It is only when medical milk commissions have been organized and a plan of education has been started to create a demand for sanitary milk designed for infant feeding that there arises any danger of an impure milk being put on the market under such a label. It is manifestly unfair, therefore, that after a commission, serving without pay in the interest of the public, has created a feeling that "certified" milk means a safe, clean milk for infant feeding, some unprincipled dairyman should be able to prey on the ignorance of the public and supply an unsafe milk at a high price. Some steps should be taken by the milk commissions or by city or State officers to prevent such practices. Where milk is an article of interstate commerce, however, the national pure-food law covers misrepresentations of this character.

LEGALIZATION OF THE TERM "CERTIFIED MILK."

The State of New York has set a good example in passing a law for regulating the sale of certified milk. A portion of the law reads as follows:

> No person shall sell or exchange, or offer or expose for sale or exchange, as and for certified milk any milk which does not conform to the regulations prescribed by, and bear the certification of, a milk commission appointed by a county medical society organized under and chartered by the Medical Society of the State of New York and which has not been pronounced by such authority to be free from antiseptics, added preservatives, and pathogenic bacteria in excessive numbers. All milk sold as certified milk shall be conspicuously marked with the name of the commission certifying it.

New Jersey has also passed a very stringent law governing the production of certified milk. This act was approved by the governor on April 21, 1909, and a section of it reads as follows:

11. No person, firm, or corporation shall sell or exchange or offer or expose for sale or exchange as and for certified milk any milk which is not produced in conformity with the methods and regulations prescribed by and which does not bear the certification of a medical milk commission, incorporated pursuant to the provisions of this act or organized or incorporated in some other State for the purposes specified in section 1 hereof, and which is not produced in conformity with the methods and regulations for the production of certified milk from time to time adopted by the American Association of Medical Milk Commissions, and which is below the standards of purity and quality for certified milk as fixed by the American Association of Medical Milk Commissions; and any such person, firm, or corporation violating any of the provisions of this section shall be guilty of a misdemeanor.

The State of Kentucky also defines certified milk in the following words:

An act for preventing the manufacturing and sale of adulterated or misbranded foods, drugs, medicines, and liquors and providing penalties for violation thereof.

Section 3, paragraph 3. If in the case of certified milk it be sold as or labeled "certified milk," and it has not been so certified under rules and regulations by any county medical society, or if, when so certified, it is not up to that degree of purity and quality necessary for infant feeding.

California has also passed a law governing certified milk, and several other States contemplate such legislation.

Michigan has seen fit to recognize the importance of this subject and has passed a law which varies somewhat from the other laws. The Michigan act provides that any board of health having two or more physicians among its membership is authorized to appoint five physicians as a medical milk commission to supervise the production of certified milk. In towns not having a board of health so constituted the State board of health may make the appointment.

FINANCIAL SUPPORT OF MILK COMMISSIONS.

Members of milk commissions rarely receive any pay for their work, their services being given gratis for the public good. Small expenses of the commission are usually met by the commission itself. Occasionally philanthropic subscriptions are received. In one city three men contributed $800 after an appeal by the commission. Postage, printing, and salaries of experts are usually paid by the producers.

There is no uniformity regarding the charges for certification. Some commissions make absolutely no charge, while others charge the actual expenses of the various inspections and examinations to

the dairymen. The following is a list of some of the charges made by different commissions at the present time:

$40 a year for each dairy.
$10 a month.
$25 a year for each 100 cows.
$8 a month for 100 quarts.
$60 a year for each dairy.
One per cent of the retail price.
One-half the cost of the bacteriological examinations.
$10 per 1,000 caps.
$5 per 1,000 caps.
$4 per 1,000 caps.
$3.50 per 1,000 caps.
$1.25 per 1,000 caps
One-third of a cent a quart.
One-fourth of a cent a quart.
One and one-half cents a quart.

It would seem that the most equitable charge for certification would be by the sale of caps bearing the seal of the commission. This is done in a majority of cases, but, as can be seen, the charges vary over a wide field.

THE AMERICAN ASSOCIATION OF MEDICAL MILK COMMISSIONS.[1]

The spread of the certified milk movement was undoubtedly retarded because of the difficulties that presented themselves to those who had such an organization in contemplation. The subject was not broadly understood by the medical profession, and even when the organization of a milk commission was determined upon it was difficult to arrive at the most acceptable plan of organization and detail of working methods.

The usual procedure was to get into correspondence with one of the older commissions, which would relate its individual way of handling this problem. If the plan submitted seemed unsatisfactory, other commissions would be written to, and so an endless correspondence resulted, which proved especially burdensome to the Newark, N. J., commission.

The secretary of the Cincinnati commission, Dr. Otto P. Geier, encountered this same difficulty at the period of organization of that commission. It resulted in his sending out a series of 24 questions covering every phase of activity in milk commission work. These were addressed to every commission then known. This very exhaustive tabulation showed that there existed considerable lack of uniformity as to organization, working methods, supervision of dairies, chemical and bacteriological standards, methods of bottling, capping, and sealing, etc.

[1] The writer is indebted to Dr. Otto P. Geier, secretary of the American Association of Medical Milk Commissions, for data regarding the organization of the association.

Out of this mass of correspondence an attempt was made to arrive at the most acceptable standards and working factors, and the conclusion was reached that a conference of the milk commissions would be most valuable to all concerned.

In February, 1907, the Cincinnati commission addressed the various milk commissions suggesting a conference to be held in connection with the meeting of the American Medical Association at Atlantic City. Out of this grew a temporary organization. Dr. Henry L. Coit, Dr. Otto P. Geier, Dr. Samuel McC. Hamill, Dr. Rowland G. Freeman, Dr. William H. Park, and Dr. Thomas W. Harvey, acting as a committee, formulated a program and called the conference for June 3, 1907, at Atlantic City.

This initial conference was remarkable in that delegates were present from 12 different States, representing 21 commissions in as many cities. Over 100 physicians and leading hygienists attended this meeting, and a tremendous amount of work was accomplished. Reports were read by delegates as to the work of their particular commissions. Papers were presented on the broad topic of a pure-milk supply for cities. A permanent organization was effected, to be known as the American Association of Medical Milk Commissions, and the following officers were elected:

President, Dr. Henry L. Coit
Secretary, Dr. Otto P. Geier.
Treasurer, Dr. Samuel McC. Hamill.
Council: Dr. Rowland G. Freeman, chairman (5 years); Dr. Henry Enos Tuley (4 years); Dr. C. W. Brown (3 years); Dr. A. W. Myers (2 years); Dr. H. L. K. Shaw (1 year); and the president, secretary, and treasurer of the association.

Committees were appointed upon every phase of activity in milk certification to investigate and report at the next annual meeting.

It can be said that this meeting marked a new era in the pure-milk crusade. It is agreed that this organization is in position to crystallize the best thought that has been given to this subject, and that through such central organization quick dissemination of that knowledge will follow.

The constitution of this association declares its object in the following language:

> The purpose of this association shall be to federate and to bring into one compact association the medical milk commissions of the United States; to exchange views and to adopt uniform methods of procedure in the work of the medical milk commissions; to fix chemical and bacteriological standards; to determine the scope of veterinary inspections; and to foster and to encourage the establishment of medical milk commissions in other cities.

A better understanding of this subject will reveal the fact that milk commissions are widening their scope, and that through their activity the quality of the general supply of milk in the large cities

is being elevated. It will show that it is practicable for any medical association to form such a commission, which, once formed, will be most useful in educating the public as well as the profession and in creating a demand for a cleaner milk supply, and will thus further the efforts of boards of health.

THE PRODUCTION OF CERTIFIED MILK.

EQUIPMENT AND METHODS.

In the following pages is given a short description of the equipment and methods that are used at the present time among the various dairies that produce certified milk.

The Dairy Division is ready at any time to furnish working blue prints for the construction of barns and milk houses in which certified milk may be produced and handled.

STABLES.

The stables in which the cows are housed for the production of certified milk are built of various materials and vary greatly as to their arrangement and cost. In the past certified stables have been built mostly of wood or brick, but of late there have been a few stables erected entirely of concrete. Feeding floors, walks, and gutters are nearly always built of cement, and in a number of cases the platform on which the cows stand is also built of this material. Some certified dairies use wood for this purpose, and a few are using cork brick for the cows to stand on.

While many of the certified barns at the present time are built with a storage loft for feed overhead, it is thought that the best practice is to have the cows in a separate one-story structure.

A great deal of money has been spent in some certified-milk plants in finishing the stable in an elaborate manner with tile and expensive trimmings. Experience would seem to show that good results can be secured in an inexpensive barn, provided the proper precautions are observed. The floors should be smooth, nonabsorbent, and easily cleaned; the gutters should be capacious; the walls and ceilings should be absolutely smooth so that they may be easily kept free from dust and other dirt. Square corners and ledges should be avoided. The barns which are most easily kept clean are built with rounded corners and no horizontal ledges where dust may accumulate. It facilitates work if running water is available in a barn, so that the floors and walls may be washed down with a hose.

At least 500 cubic feet of air space and 4 square feet of window glass per cow should be allowed. Many certified stables are built with a much greater window allowance. Sunlight acts as a disinfectant in the stable and adds much to the attractiveness of the building.

Views of stables are shown in Plates I and II.

DAIRY HOUSES.

Milk houses on certified farms vary almost as greatly as do the stables. Stone, brick, wood, and cement are used for their construction. The same rules regarding the absence of ledges and the smoothness of the walls, floors, and ceilings should be observed. An entirely separate room should be provided for handling the milk, and in the majority of certified dairies this room is kept tightly closed while milk is being bottled and no visitors are allowed access to it. In some of the milk rooms air is supplied through a filter, so that there is no danger of bacteria being admitted from the outside air. Screens should be provided for all openings in the milk house, and there is no excuse for flies in the milk room.

HEALTH AND CLEANLINESS OF CATTLE.

The medical milk commissions require the tuberculin testing of the herds under their supervision. In addition, any cows showing abnormal symptoms or any form of disease which might affect the milk are eliminated from certified herds. The cattle are carefully groomed at least once a day so that there can be no accumulation of filth upon them, and in many dairies the cows' tails are washed daily. Many certified-milk producers are in the habit of clipping the hairs from the udders, flanks, legs, and bellies of all the animals, so that they are the more readily kept clean. A few certified dairies have installed vacuum cleaners with which the cows are cleaned previous to milking. These cleaners take up much of the dust, loose hairs, and scurf which would simply be brushed into the air of the stable by hand cleaning. After the cows are cleaned they are fastened so that they can not lie down until the milkers are through.

REMOVAL OF MANURE.

Wherever practicable the manure should be carried to the field daily. Many dairies follow this custom and find it economical, in that the manure does not have to be handled twice, as it would were it kept in a pit. At other dairies covered pits are built for the reception of the manure. Where these are built they should be of water-tight construction and should be tightly screened and covered to keep out flies.

BEDDING.

While straw is used for bedding in some of the certified dairies, a large number use either planer shavings or sawdust. Baled shavings may be had at a nominal price and make a very satisfactory bedding in sanitary dairies. As fast as these shavings are soiled or become damp they should be removed with the manure and replaced with clean, dry shavings.

FEEDING.

On account of the dust and odors which arise from the feeding of hay, grain, and silage, nearly all certified dairies prefer to do the feeding after milking has been completed.

BARNYARD.

The barnyard should be well drained and kept free from all filth. If good natural drainage can not be secured it is sometimes necessary to fill in the barnyard with coal ashes, gravel, shells, or some other drainage material. Sometimes underdrains are put in to carry away superfluous moisture. As the cows often lie down in the barnyard,

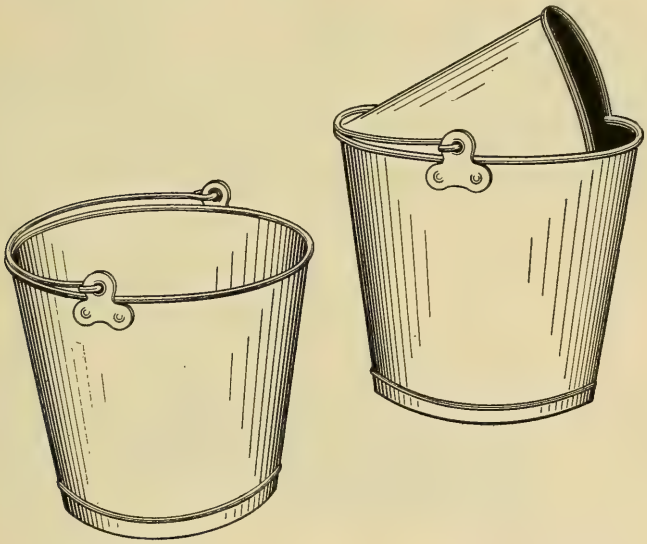


FIG. 1.—Ordinary milk pail made into a small-top pail by the addition of a hood.

it is important to keep the yard clean, so that they may not become unnecessarily dirty.

UTENSILS.

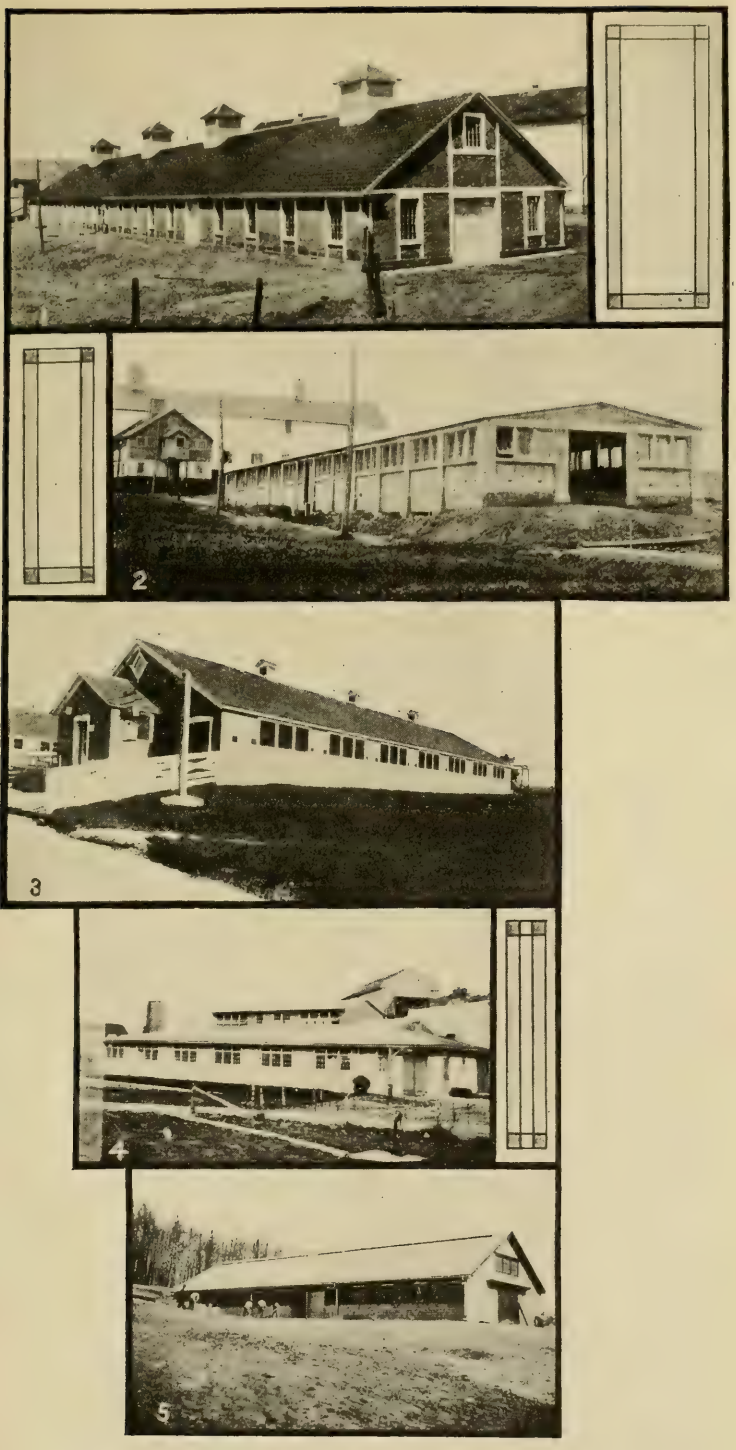
Particular attention is paid by certified dairies to the construction of the utensils which come in contact with the milk. It is most desirable to have the utensils as free as possible from all crevices and inaccessible parts. The simplest utensils are the ones which are the most readily cleaned, and hence the danger of contamination from them is less. Small-top milk pails are used by practically every certified dairy. There are many forms of the small-top milk pail in use at the present time, and it is generally known that these pails are responsible for the elimination of many bacteria from milk. Figure 1 shows a small-top pail which can be made from an ordinary milk pail by the addition of a hood. This pail will take the place of some of the more expensive kinds and do very satisfactory work.

In considering the purchase of a sanitary milk pail two things must be considered—first, its practicability, and, second, the ease with which it can be cleaned. Some of the so-called sanitary pails have proved to be too cumbersome and unwieldy for practical use, while others have spouts, sharp angles, and inaccessible places that are extremely difficult to clean. It is usually the practice to fill all of the seams and corners in milk utensils with solder, so that a smooth, cleanable surface is presented.

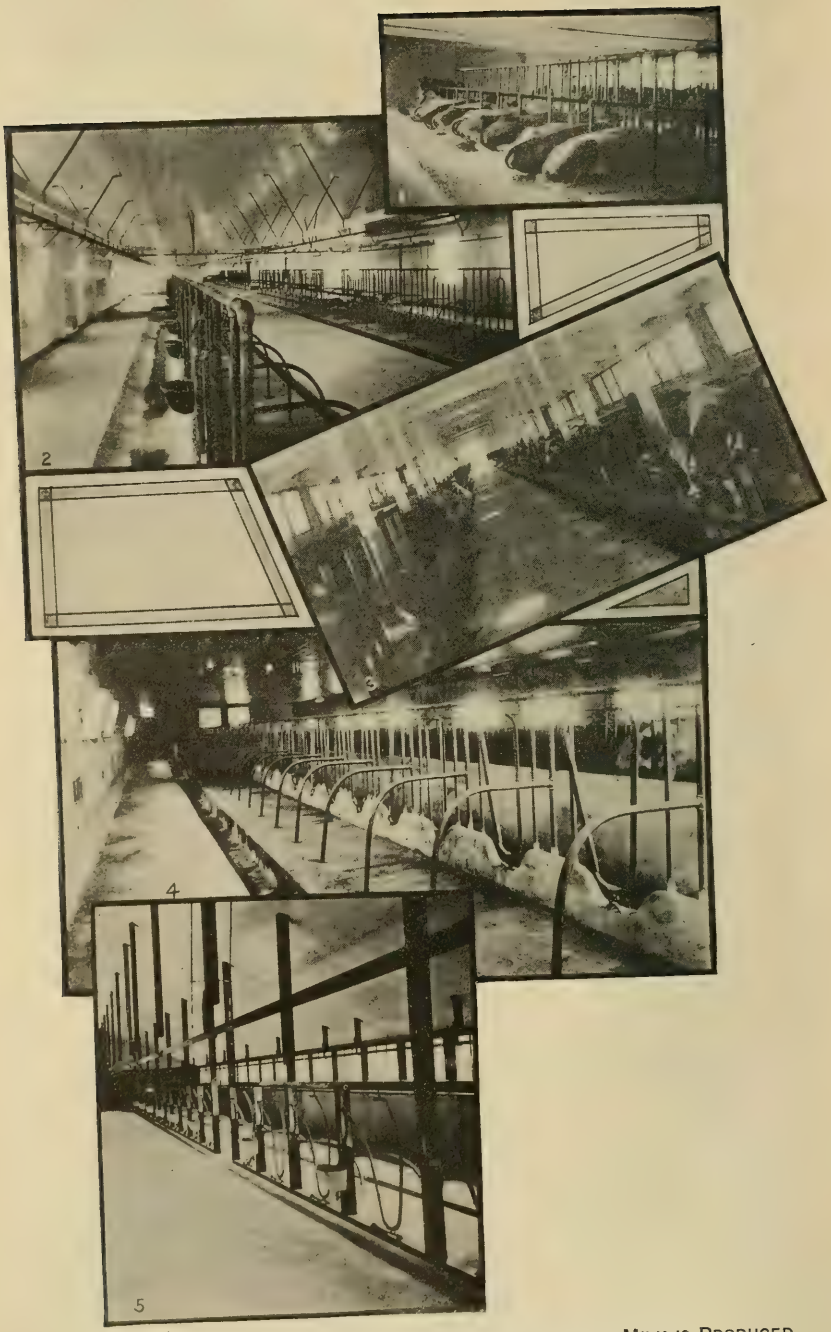
At practically all of the certified dairies steam is used for the sterilization of utensils, including bottles, cans, milk pails, strainers, and in some cases even the coolers and bottle fillers. This sterilization is done in large ovens, which can be bought ready-made or can be built by the owner of the plant. (See Pl. IV, fig. 12.) In these sterilizers the utensils are sterilized with live steam, usually for a half hour and sometimes under a slight pressure. These sterilizers are constructed of cement, brick, iron, and in one dairy the sterilizer in use is lined with glass enamel, which makes a smooth, cleanable surface. In many certified dairies the custom is practiced of sterilizing the milk pails and other utensils and leaving them inverted in the sterilizer until milking time. This protects them from contamination due to flies or impure outside air.

PREPARATION FOR MILKING.

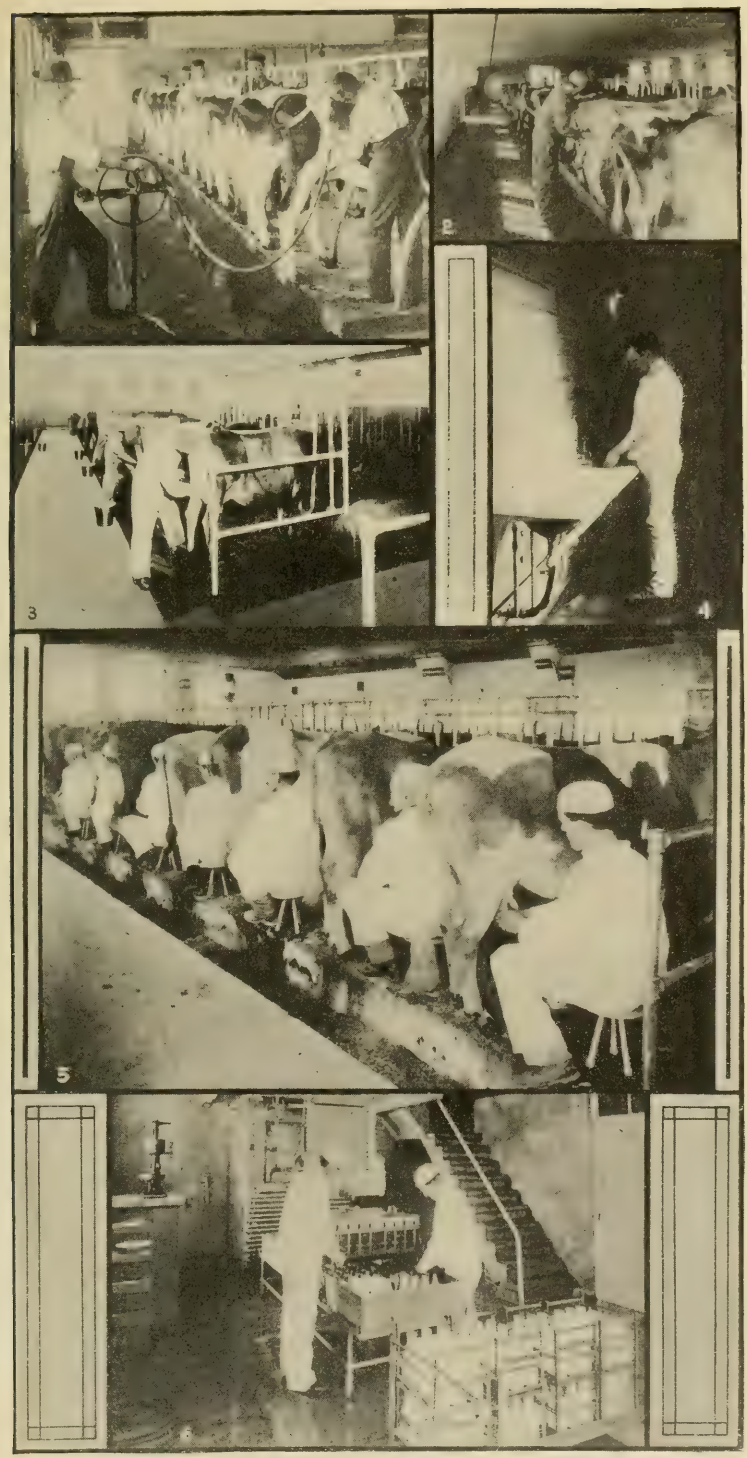
At all certified dairies great care is exercised to see that the stable air is free from dust and odors at milking time. The cows are groomed and the floors are swept long enough before milking so that the dust has had a chance to settle. Some dairies make a practice of spraying the air in the barn and the bedding with a fine spray of water just previous to milking, so that all dust particles are laid. At one dairy this result is achieved by the use of steam. Pipes pierced with holes run horizontally through the barn, and just before milking steam is turned into them. One disadvantage of this method is that it raises the temperature in the barn considerably in the summer time. Before milking, the cows are usually cleaned by a separate gang of men. In a few places the milkers wash the cows just before they milk them, but this is not considered so satisfactory on account of the fact that the milkers' hands are apt to be contaminated from the wash water, and unless they are careful to clean them each time there may be bad results. The cow-cleaning gang usually consists of three or four men, who thoroughly prepare the cows for the milkers. One of these men sometimes uses a damp towel or a piece of sacking with which he wipes off the body of the cow to remove any loose hairs or dust which have not been removed by previous grooming. Then the cow's udder and flanks are washed, usually in two separate waters, care being taken to change the water often enough so that it does



EXTERIOR VIEWS OF DAIRY STABLES WHERE CERTIFIED MILK IS PRODUCED.



INTERIOR VIEWS OF DAIRY STABLES WHERE CERTIFIED MILK IS PRODUCED.



STEPS IN THE PRODUCTION AND HANDLING OF CERTIFIED MILK.

1. Clipping cows. 2. Cleaning cows. 3. Washing cows preparatory to milking. 4. Milker washing hands. 5. Milking. 6. Cooling and bottling.

STEPS IN THE HANDLING AND DELIVERY OF CERTIFIED MILK.

7. Sealing bottles. 8. Storage. 9. Case of bottles ready for delivery. 10. Delivery wagon. 11. Washing bottles. 12. Sterilizing bottles.

OUTSIDE COVERINGS USED TO PROTECT BOTTLE MOUTHS FROM CONTAMINATION.

not do more harm than good. In some certified dairies a disinfectant is used in this water, but in the majority of cases plain water is used. After washing, the cows are usually partially dried with a clean towel, the object being to have the cows' hides slightly moist, but not wet enough for any moisture to run on the milkers' hands or drip into the pail.

While the cows are being prepared the milkers assemble in the dressing room and put on their clean milking suits and thoroughly scrub their hands and finger nails with soap and brushes. In a few dairies the requirements for the cleanliness of the milkers are so rigid that only smooth-shaven men are allowed to milk the cows or have anything to do with handling the milk. When the milkers are satisfactorily prepared for milking they are handed sterilized milk pails and milking stools and allowed to start work. In some dairies the cows are milked in a room separate from the stable. This room holds only a few cows at a time, the cows being cleaned in the main barn and led into the milking room to be milked. Judging from the bacterial counts of the various dairies there is nothing specially gained by this, if proper precautions are taken in the main barn.

MILKING.

In a few dairies the milkers use a little vaseline on the hands while milking, but in practically all cases milking is done with dry hands. It is very often the practice to discard the first few streams of milk from each cow, which are drawn into a cup. This "foremilk" contains large numbers of bacteria, and the count can be reduced by rejecting it.

Milkers are instructed to milk quickly and quietly, and after each cow is finished they carry the milk to the straining room, where it is strained and cooled immediately. By far the best method is to require the milkers to wash their hands after milking each cow. Plenty of clean towels should be provided for the purpose of wiping the milkers' hands. In one dairy paper towels are being used, so that perfectly fresh unused towels are at hand for each milker. During the milking the milkers should not be allowed to rest the milk pail on the floor, as the bottom of the pail is liable to become covered with dirt, which is transferred to the milkers' hands when he pours the milk from the pail.

SUBSEQUENT HANDLING OF MILK.

The milk is removed immediately from the barn to the milk house, where it is cooled and bottled at once. In some dairies the milk is bottled warm and the bottles are packed in ice or stood in ice water. This eliminates much exposure to the air. Various types of bottle fillers are in use in the large dairies, while one or two of

the very smallest fill the bottles from a large dipper or pitcher. In the last few years capping machines have been perfected so that the bottles may be filled and capped without being touched by human hands. This is a decided advantage, as the old method of placing the caps in the bottles by hand was liable to result in serious contamination. Practically all of the certified establishments sterilize the caps which are used in the milk bottles. This sterilization is best accomplished by dry heat, as steam is apt to swell the paper caps so that they do not fit the capping machine or the neck of the bottle. The caps are placed in a small cylinder or rolled in brown paper and placed in dry ovens, where they are heated for about an hour.

Practically all certified-milk dairies now use some sort of an outside cover to protect the mouth of the bottle from being infected with dust or dirty water. A variety of appliances for this purpose are in use, some of which are shown in Plate V.

TRANSPORTATION AND DELIVERY.

Great care is taken to see that certified milk is always kept cold. It is cooled in the dairies by ice water, brine, or direct expansion almost down to the freezing point, and from that time until it is delivered to the consumer it is kept well packed in ice to prevent the multiplication of bacteria.

The distribution of certified milk is done in some cases by the producer, but very often the producer ships to some retailer in the city, who handles the product for him.

Some certified dairies maintain laboratories in charge of physicians or trained nurses where certified milk is modified for infant feeding according to physicians' prescriptions. The modified milk is put up in nursing bottles, sufficient feedings for one day being prepared at a time and delivered to the consumer in a refrigerator case.

INFORMATION SECURED FROM PRODUCERS.

In order to secure accurate data relative to the production of certified milk, a list of questions was sent to owners and operators of certified-milk farms. Answers were received from a large number. It was found that quite a number had discontinued the production of certified milk for one reason or another, several having stopped because of the lack of sufficient markets for their product or because the production was attended with financial loss. Answers to the questions were received from 92 dairies, distributed among 17 States.

NUMBER AND BREED OF COWS.

The number of cows in herds producing certified milk varies from 9 to 600. It was found that the average number of cows in certified dairies was 88. Practically every breed is represented in these herds.

Some grade or native stock is found in most of them. There are several herds of registered animals. The breed is not considered of special importance with most of the commissions, provided that the composition of the milk produced is within the limits of the standards prescribed. Provided that the health of the animals is perfect, it makes very little difference apparently what the breed is.

QUANTITY AND QUALITY OF THE MILK.

The amount of certified milk produced daily by certified dairies ranged from 12½ to 6,000 quarts. The average daily production per dairy was found to be 747½ quarts. The average production of all the cows of all the dairies reporting is somewhat higher than that found in market milk dairies, but it is still far too low. An average of all the answers received showed that the production amounted to 8.3 quarts of milk per cow per day. The fat in the milk as reported varies from 3.2 to 6 per cent, and averages about 4.3 per cent. This is a slightly lower average than was found in the investigations made in 1907. The total solids as reported by the various dairies ranged from 11.74 to 14.5 per cent, with an average for all dairies of an even 13 per cent.

BACTERIA IN THE MILK.

The average bacterial counts of the milk from the dairies reporting varied considerably. One dairy claimed that their count ranges from absolutely sterile plates up to 1,000 bacteria per cubic centimeter. Three dairies reported counts of 20,000. The average bacterial count of all the dairies reporting was 4,069 per cubic centimeter. Some extremely low averages were reported, one dairy having an average count for one year of 655 bacteria per cubic centimeter. Still another dairy reported a seven weeks' average of 600 bacteria per cubic centimeter.

RETAIL PRICES OF CERTIFIED MILK.

The producers' reports on the retail price of their product shows that the lowest price received is 10 cents a quart, which price was reported by four dairies. The highest retail price was 20 cents a quart, which is received by two dairies. Averaging all the replies, it was found that the average retail price of certified milk is 14.3 cents a quart.

AGE OF MILK WHEN DELIVERED.

Milk commissions have striven for the delivery of certified milk as soon after it is produced as possible; all other things being equal, the sooner it is delivered and consumed the better. In answer to the question as to the average age of certified milk when delivered, 92 producers returned answers which showed that some milk was

delivered within 6 hours after its production, while some was not placed on the market until it was 48 hours old. The average age when delivered was 20 hours. As some of this milk will not be used until 24 hours after its delivery, it is possible for some certified milk to be consumed after it is 72 hours old.

SANITARY CONDITION OF CERTIFIED-MILK DAIRIES.

In the past about 37 certified farms have been scored by representatives of the Dairy Division. An average of all these scores shows that the condition of certified-milk farms is about 90 points out of a possible 100. This is a remarkably good showing, in view of the fact that to attain a mark of 100 conditions must be absolutely perfect in every respect; that is, that not a speck of dust or dirt could be found on the cattle or in the stables or milk house and that everything else was above criticism in every respect. That certified dairies have maintained a high standard is evidenced by the comparison of their standing with the scores of ordinary dairies in general. Dairies supplying market milk to various cities in this country have been scored and will average between 40 and 45, depending upon the section of the country and the efficiency of the inspection system which governs them. A total of 953 dairies, the scores of which were filed in this division in one year, show an average score of 41.6 out of a possible 100; so that it will be seen that the average certified dairy scores more than twice as high as the average market-milk dairy. The lowest score of a certified-milk dairy of which there is any record in this department is 73.6.

QUALITY OF CERTIFIED MILK.

An index to the quality of certified milk is the result of complete analyses and examinations of this product at various milk contests, descriptions of which will be found in Bureau of Animal Industry Circular 205. Eighty-nine samples of certified milk and cream were scored in these contests, and the average score was 87.96 for certified milk and 87.82 for certified cream. The greatest fault in these samples was that relating to flavor and odor rather than to the bacterial count. When it is realized that in order to score perfect on bacterial count in these contests the average number of organisms found must be less than 400 to the cubic centimeter, it will readily be seen that certified milk has maintained a high standard as regards quality. Certified milk and cream both scored considerably higher than did milk and cream in the market classes. The average bacterial count for all the samples of certified milk submitted in these contests was between 7,000 and 8,000 to the cubic centimeter. It must be remembered that many of these samples were prepared especially for the

contests, so that they indicate a knowledge of dairy sanitation and do not necessarily mean a uniform product of the same high quality.

KEEPING QUALITIES OF CERTIFIED MILK.

As would naturally be expected, certified milk with its small number of bacteria will keep sweet for a long time. The theory that clean milk should have a long keeping quality works out in practice. Instances are on record where certified milk has been taken on an ocean voyage and not only brought back in good condition but kept sweet until 30 days old. In fact, it is now a common practice for people when crossing the water or taking a long land journey with infants to take several cases of certified milk with them. They are then reasonably sure of having a constant supply of sweet milk for several days. This has been a great convenience and has given comfort to many people.

A number of certified-milk dairies in the United States sent exhibits of milk to the Paris Exposition in 1900. The milk kept perfectly sweet for two weeks and in some instances 18 days after being bottled and after a summer journey of 3,000 to 4,000 miles. Regular delivery bottles were used, the only extra precaution being to use two paper caps instead of one, and to cover the caps with paraffin so as to exclude the air. Of course the milk was carefully packed in ice for shipment, but this was the only means used for preservation.

The milk and cream contests at the National Dairy Show in recent years have demonstrated the remarkable keeping qualities of certified milk. Some of the samples submitted have come to Chicago from as far as the States of Washington and California, and from various parts of Canada. Though these samples have some of them been over a week old when plated, they have shown remarkably low bacterial counts, in some instances the count being less than 1,000 per cubic centimeter. After this milk has been judged it has been kept in cold storage, and some has been consumed over two weeks after its production, when it was found perfectly palatable and apparently unchanged in any way.

However, it is not advisable to use old milk even though it may taste sweet. Serious consequences may result due to bacterial growth which can not be detected in the flavor of the milk.

IS THE PRODUCTION OF CERTIFIED MILK PROFITABLE?

At the present time the unqualified statement can not be made that the production of certified milk is a profitable venture. Seventy-four certified-milk producers answered the questions sent out by the Dairy Division as to the profitableness of certified-milk production, and their answers may be grouped as follows: Unprofitable, 33; profitable, 22; not very profitable, 4; fairly profitable, 11; condi-

tional answers, 4. The conditional answers included 3 which stated that the business was profitable only part of the time, and 1 which stated that it would be profitable if the markets for the product were larger. These answers can not be considered as favorable to the profitable production of certified milk, so a regrouping would give: Profitable, 37; unprofitable, 37.

Out of the 37 dairies which are classed as profitable there are 15 which state that the business is not very profitable or only fairly so. There is very little doubt that certified milk can be produced and sold at a fair profit, as this is being done by many dairies at the present time. However, the large number of unprofitable dairies shows that there is need for a radical change in the methods of many of the farms which are producing this class of milk. It is unquestionably the fact that many certified-milk producers can lower the price of production by applying better business principles to their operations, and this will undoubtedly result in a swinging of the balance from loss to profit on their books.

OBSTACLES TO THE PROFITABLE PRODUCTION OF CERTIFIED MILK.

To support the statement that some certified dairies are run under lax business methods, it is only necessary to point to a few figures received by this department. For instance, one dairy reports that the retail price of milk is 20 cents a quart, the average bacterial count is 4,000 per cubic centimeter, and that the business is not profitable and it would require a retail price of 25 cents a quart to make it so. Another dairy states that the retail price is only 12 cents, the bacterial count 3,000 (less than in the case of the other dairy), and that the business is profitable. There is a difference of 8 cents a quart in favor of the first dairy, and yet with that advantage it is unable to conduct the business at a profit.

Many certified-milk producers have erected extremely elaborate buildings, the interest and depreciation on which are so high that they form a considerable item to be charged against the cost of production. The interest and depreciation on a simple, inexpensive certified plant is estimated to amount to at least 6 cents a gallon, or 1½ cents a quart. In some of the more elaborate plants, where much money has been spent for ornamental equipment, the interest and depreciation would be much higher. Experience in the past has proved that the production of clean milk is not dependent upon expensive equipment so much as upon care and vigilance concerning the methods of production. It is a well-known fact in business that a manufacturing plant can not afford to turn out such a small quantity of goods that the interest and depreciation on the factory will be too heavy a tax on the goods sold. Applying this same principle to dairying, it is almost impossible to see where some of the small dairies can afford to operate

as they do. One dairy reports that they are selling only 12½ quarts of certified milk a day, and the interest and depreciation on the capital invested in this plant will certainly amount to quite a large item per quart on all the milk sold. Another plant reports a daily selling of 30 quarts, and another of only 120 quarts.

The average production of milk per cow in certified dairies shows that many unprofitable animals are probably being kept, and a thorough system of record keeping should be inaugurated in order to weed out the low producers. One dairy reports that the average test of the milk is 6 per cent fat, and it is hard to see how such milk can be profitably sold in competition with 4 per cent milk. In order to improve the herds from year to year calves should be raised from the best producing cows. Here again is another item of added expense on the certified dairy, as the raising of calves is an expensive proposition, especially where milk valued at from 15 to 20 cents a quart is used. If calves are not raised and cows are bought from the outside there is little chance of bettering the herd.

On most certified farms a higher class of labor is utilized than on the ordinary dairy farm. Many college graduates are employed as foremen, managers, or bacteriologists, and such men usually command higher salaries.

Markets for certified milk at the present time are not developed sufficiently. Several of the certified dairies reporting that the production of this product was unprofitable intimated that if more milk could be sold and the plant operated at a greater capacity a profit might be realized. The general public so far has very little idea as to what certified milk really is, and an educational campaign might well be carried on by the producers. In addition to this, lax methods on some farms have necessitated a high price for certified milk, and this has cut down the consumption considerably.

There seems to be little uniformity regarding the distribution of certified milk. Some of the methods now in vogue seem to be to the disadvantage of the producer. Of the producers reporting, 25 retail the product of their dairies, while 47 do not. From the answers received it appears to be more economical to distribute through a middleman, especially where the points of production and distribution are widely separated. The middleman has the advantage of already maintaining an establishment in the city and of running regular retail routes on which the certified milk can be distributed quite economically. Some of these distributers of certified milk seem to charge the producer a rather high rate for their services. Many city dealers buy market milk from farmers and receive from 14 to 19 cents a gallon to cover the cost of freight, bottling, and distribution, besides giving them their profit. Certified milk is nearly always bottled at the farm, so that the expense of handling in the city is much smaller.

Figures submitted to this department, however, show out of 50 cents a gallon paid by consumers for certified milk from one farm, the producer got 26 cents, the freight was 4 cents, and the middleman charged 20 cents a gallon for his services in distributing the product. Another dairy receives 12 cents out of a retail price of 15 cents a quart, leaving the distributer 12 cents a gallon. In one case the middleman received 5 cents a quart for distribution, while the other received 3 cents.

THE FUTURE OF CERTIFIED MILK.

There is no doubt that from a sanitary standpoint certified milk is constantly improving, and it will undoubtedly continue to lead all classes of milk as a food for infants. It seems almost imperative, however, that business principles be more closely applied to the production of certified milk, so that the price may be kept as low as possible to the consumer and still let the farmers operate at a profit. Upon this one factor depends much of the future growth of the movement. It is very probable that certified-milk producers in the future will apply the same degree of intelligence and care to the economic features of their business as they have in the past to the sanitary side.

THE CERTIFIED MILK PRODUCERS' ASSOCIATION.

In order to disseminate information among themselves concerning methods employed in the production of certified milk, producers of this class of dairy products have formed an organization under the name of The Certified Milk Producers' Association of America. Yearly meetings are held at which papers are read which deal with the production of certified milk, both from a financial standpoint and concerning sanitation.

APPENDIX.

METHODS AND STANDARDS FOR THE PRODUCTION AND DISTRIBUTION OF CERTIFIED MILK.

(Adopted by the American Association of Medical Milk Commissions, May 1, 1912.)

HYGIENE OF THE DAIRY.

UNDER THE SUPERVISION AND CONTROL OF THE VETERINARIAN.

1. *Pastures or paddocks.*—Pastures or paddocks to which the cows have access shall be free from marshes or stagnant pools, crossed by no stream which might become dangerously contaminated, at sufficient distances from offensive conditions to suffer no bad effects from them, and shall be free from plants which affect the milk deleteriously.

2. *Surroundings of buildings.*—The surroundings of all buildings shall be kept clean and free from accumulations of dirt, rubbish, decayed vegetable or animal matter or animal waste, and the stable yard shall be well drained.

3. *Location of buildings.*—Buildings in which certified milk is produced and handled shall be so located as to insure proper shelter and good drainage, and at sufficient distance from other buildings, dusty roads, cultivated and dusty fields, and all other possible sources of contamination; provided, in the case of unavoidable proximity to dusty roads or fields, the exposed side shall be screened with cheesecloth.

4. *Construction of stables.*—The stables shall be constructed so as to facilitate the prompt and easy removal of waste products. The floors and platforms shall be made of cement or other nonabsorbent material and the gutters of cement only. The floors shall be properly graded and drained, and the manure gutters shall be from 6 to 8 inches deep and so placed in relation to the platform that all manure will drop into them.

5. The inside surface of the walls and all interior construction shall be smooth, with tight joints, and shall be capable of shedding water. The ceiling shall be of smooth material and dust tight. All horizontal and slanting surfaces which might harbor dust shall be avoided.

6. *Drinking and feed troughs.*—Drinking troughs or basins shall be drained and cleaned each day, and feed troughs and mixing floors shall be kept in a clean and sanitary condition.

7. *Stanchions.*—Stanchions, when used, shall be constructed of iron pipes or hardwood, and throat latches shall be provided to prevent the cows from lying down between the time of cleaning and the time of milking.

8. *Ventilation.*—The cow stables shall be provided with adequate ventilation either by means of some approved artificial device, or by the substitution of cheesecloth for glass in the windows, each cow to be provided with a minimum of 600 cubic feet of air space.

9. *Windows.*—A sufficient number of windows shall be installed and so distributed as to provide satisfactory light and a maximum of sunshine, 2 feet

square of window area to each 600 cubic feet of air space to represent the minimum. The coverings of such windows shall be kept free from dust and dirt.

10. *Exclusion of flies, etc.*—All necessary measures should be taken to prevent the entrance of flies and other insects and rats and other vermin into all the buildings.

11. *Exclusion of animals from the herd.*—No horses, hogs, dogs, or other animals or fowls shall be allowed to come in contact with the certified herd, either in the stables or elsewhere.

12. *Bedding.*—No dusty or moldy hay or straw, bedding from horse stalls, or other unclean materials shall be used for bedding the cows. Only bedding which is clean, dry, and absorbent may be used, preferably shavings or straw.

13. *Cleaning stable and disposal of manure.*—Soiled bedding and manure shall be removed at least twice daily, and the floors shall be swept and kept free from refuse. Such cleaning shall be done at least one hour before the milking time. Manure, when removed, shall be drawn to the field or temporarily stored in containers so screened as to exclude flies. Manure shall not be even temporarily stored within 300 feet of the barn or dairy building.

14. *Cleaning of cows.* Each cow in the herd shall be groomed daily, and no manure, mud, or filth shall be allowed to remain upon her during milking; for cleaning, a vacuum apparatus is recommended.

15. *Clipping.*—Long hairs shall be clipped from the udder and flanks of the cow and from the tail above the brush. The hair on the tail shall be cut so that the brush may be well above the ground.

16. *Cleaning of udders.*—The udders and teats of the cow shall be cleaned before milking; they shall be washed with a cloth and water, and dry wiped with another clean sterilized cloth—a separate cloth for drying each cow.

17. *Feeding.*—All foodstuffs shall be kept in an apartment separate from and not directly communicating with the cow barn. They shall be brought into the barn only immediately before the feeding hour, which shall follow the milking.

18. Only those foods shall be used which consist of fresh, palatable, or nutritious materials, such as will not injure the health of the cows or unfavorably affect the taste or character of the milk. Any dirty or moldy food or food in a state of decomposition or putrefaction shall not be given.

19. A well-balanced ration shall be used, and all changes of food shall be made slowly. The first few feedings of grass, alfalfa, ensilage, green corn, or other green feeds shall be given in small rations and increased gradually to full ration.

20. *Exercise.*—All dairy cows shall be turned out for exercise at least 2 hours in each 24 in suitable weather. Exercise yards shall be kept free from manure and other filth.

21. *Washing of hands.*—Conveniently located facilities shall be provided for the milkers to wash in before and during milking.

22. The hands of the milkers shall be thoroughly washed with soap, water, and brush and carefully dried on a clean towel immediately before milking. The hands of the milkers shall be rinsed with clean water and carefully dried before milking each cow. The practice of moistening the hands with milk is forbidden.

23. *Milking clothes.*—Clean overalls, jumper, and cap shall be worn during milking. They shall be washed or sterilized each day and used for no other purpose, and when not in use they shall be kept in a clean place, protected from dust and dirt.

24. *Things to be avoided by milkers.*—While engaged about the dairy or in handling the milk employees shall not use tobacco nor intoxicating liquors.

They shall keep their fingers away from their nose and mouth, and no milker shall permit his hands, fingers, lips, or tongue to come in contact with milk intended for sale.

25. During milking the milkers shall be careful not to touch anything but the clean top of the milking stool, the milk pail, and the cow's teats.

26. Milkers are forbidden to spit upon the walls or floors of stables, or upon the walls or floors of milk houses, or into the water used for cooling the milk or washing the utensils.

27. *Fore milk.*—The first streams from each teat shall be rejected, as this fore milk contains large numbers of bacteria. Such milk shall be collected into a separate vessel and not milked onto the floors or into the gutters. The milking shall be done rapidly and quietly, and the cows shall be treated kindly.

28. *Milk and calving period.*—Milk from all cows shall be excluded for a period of 45 days before and 7 days after parturition.

29. *Bloody and stringy milk.*—If milk from any cow is bloody and stringy or of unnatural appearance, the milk from that cow shall be rejected and the cow isolated from the herd until the cause of such abnormal appearance has been determined and removed, special attention being given in the meantime to the feeding or to possible injuries. If dirt gets into the pail, the milk shall be discarded and the pail washed before it is used.

30. *Make-up of herd.*—No cows except those receiving the same supervision and care as the certified herd shall be kept in the same barn or brought in contact with them.

31. *Employees other than milkers.*—The requirements for milkers, relative to garments and cleaning of hands, shall apply to all other persons handling the milk, and children unattended by adults shall not be allowed in the dairy nor in the stable during milking.

32. *Straining and strainers.*—Promptly after the milk is drawn it shall be removed from the stable to a clean room and then emptied from the milk pail to the can, being strained through strainers made of a double layer of finely meshed cheesecloth or absorbent cotton thoroughly sterilized. Several strainers shall be provided for each milking in order that they may be frequently changed.

33. *Dairy building.*—A dairy building shall be provided which shall be located at a distance from the stable and dwelling prescribed by the local commission, and there shall be no hogpen, privy, or manure pile at a higher level or within 300 feet of it.

34. The dairy building shall be kept clean and shall not be used for purposes other than the handling and storing of milk and milk utensils. It shall be provided with light and ventilation, and the floors shall be graded and water-tight.

35. The dairy building shall be well lighted and screened and drained through well-trapped pipes. No animals shall be allowed therein. No part of the dairy building shall be used for dwelling or lodging purposes, and the bottling room shall be used for no other purpose than to provide a place for clean milk utensils and for handling the milk. During bottling this room shall be entered only by persons employed therein. The bottling room shall be kept scrupulously clean and free from odors.

36. *Temperature of milk.*—Proper cooling to reduce the temperature to 45° F. shall be used, and aerators shall be so situated that they can be protected from flies, dust, and odors. The milk shall be cooled immediately after being milked, and maintained at a temperature between 35° and 45° F. until delivered to the consumer.

37. *Sealing of bottles.*—Milk, after being cooled and bottled, shall be immediately sealed in a manner satisfactory to the commission, but such seal shall include a sterile hood which completely covers the lip of the bottle.

38. *Cleaning and sterilizing of bottles.*—The dairy building shall be provided with approved apparatus for the cleansing and sterilizing of all bottles and utensils used in milk production. All bottles and utensils shall be thoroughly cleaned by hot water and sal soda, or equally pure agent, rinsed until the cleaning water is thoroughly removed, then exposed to live steam or boiling water at least 20 minutes, and then kept inverted until used, in a place free from dust and other contaminating materials.

39. *Utensils.*—All utensils shall be so constructed as to be easily cleaned. The milk pail should preferably have an elliptical opening 5 by 7 inches in diameter. The cover of this pail should be so convex as to make the entire interior of the pail visible and accessible for cleaning. The pail shall be made of heavy seamless tin, and with seams which are flushed and made smooth by solder. Wooden pails, galvanized-iron pails, or pails made of rough, porous materials, are forbidden. All utensils used in milking shall be kept in good repair.

40. *Water supply.*—The entire water supply shall be absolutely free from contamination, and shall be sufficient for all dairy purposes. It shall be protected against flood or surface drainage, and shall be conveniently situated in relation to the milk house.

41. *Privies, etc., in relation to water supply.*—Privies, pigpens, manure piles, and all other possible sources of contamination shall be so situated on the farm as to render impossible the contamination of the water supply, and shall be so protected by use of screens and other measures as to prevent their becoming breeding grounds for flies.

42. *Toilet rooms.*—Toilet facilities for the milkers shall be provided and located outside of the stable or milk house. These toilets shall be properly screened, shall be kept clean, and shall be accessible to wash basins, water, nail brush, soap and towels, and the milkers shall be required to wash and dry their hands immediately after leaving the toilet room.

TRANSPORTATION.

43. In transit the milk packages shall be kept free from dust and dirt. The wagon, trays, and crates shall be kept scrupulously clean. No bottles shall be collected from houses in which communicable diseases prevail, unless a separate wagon is used and under conditions prescribed by the department of health and the medical milk commission.

44. All certified milk shall reach the consumer within 30 hours after milking.

VETERINARY SUPERVISION OF THE HERD.

45. *Tuberculin test.*—The herd shall be free from tuberculosis, as shown by the proper application of the tuberculin test. The test shall be applied in accordance with the rules and regulations of the United States Government, and all reactors shall be removed immediately from the farm.[1]

46. No new animals shall be admitted to the herd without first having passed a satisfactory tuberculin test, made in accordance with the rules and regulations mentioned; the tuberculin to be obtained and applied only by the official veterinarian of the commission.

47. Immediately following the application of the tuberculin test to a herd for the purpose of eliminating tuberculous cattle, the cow stable and exercising yards shall be disinfected by the veterinary inspector in accordance with the rules and regulations of the United States Government.

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[1] See Circular of Instructions issued by the Bureau of Animal Industry for making tuberculin tests and for disinfection of premises.

48. A second tuberculin test shall follow each primary test after an interval of six months, and shall be applied in accordance with the rules and regulations mentioned. Thereafter, tuberculin tests shall be reapplied annually, but it is recommended that the retests be applied semiannually.

49. *Identification of cows.*—Each dairy cow in each of the certified herds shall be labeled or tagged with a number or mark which will permanently identify her.

50. *Herd-book record.*—Each cow in the herd shall be registered in a herd book, which register shall be accurately kept so that her entrance and departure from the herd and her tuberculin testing can be identified.

51. A copy of this herd-book record shall be kept in the hands of the veterinarian of the medical milk commission under which the dairy farm is operating, and the veterinarian shall be made responsible for the accuracy of this record.

52. *Dates of tuberculin tests.*—The dates of the annual tuberculin tests shall be definitely arranged by the medical milk commission, and all of the results of such tests shall be recorded by the veterinarian and regularly reported to the secretary of the medical milk commission issuing the certificate.

53. The results of all tuberculin tests shall be kept on file by each medical milk commission, and a copy of all such tests shall be made available to the American Association of Medical Milk Commissions for statistical purposes.

54. The proper designated officers of the American Association of Medical Milk Commissions should receive copies of reports of all of the annual, semiannual, and other official tuberculin tests which are made and keep copies of the same on file and compile them annually for the use of the association.

55. *Disposition of cows sick with diseases other than tuberculosis.*—Cows having rheumatism, leucorrhea, inflammation of the uterus, severe diarrhea, or disease of the udder, or cows that from any other cause may be a menace to the herd shall be removed from the herd and placed in a building separate from that which may be used for the isolation of cows with tuberculosis, unless such building has been properly disinfected since it was last used for this purpose. The milk from such cows shall not be used nor shall the cows be restored to the herd until permission has been given by the veterinary inspector after a careful physical examination.

56. *Notification of veterinary inspector.*—In the event of the occurrence of any of the diseases just described between the visits of the veterinary inspector, or if at any time a number of cows become sick at one time in such a way as to suggest the outbreak of a contagious disease or poisoning, it shall be the duty of the dairyman to withdraw such sickened cattle from the herd, to destroy their milk, and to notify the veterinary inspector by telegraph or telephone immediately.

57. *Emaciated cows.*—Cows that are emaciated from chronic diseases or from any cause that in the opinion of the veterinary inspector may endanger the quality of the milk, shall be removed from the herd.

BACTERIOLOGICAL STANDARDS.

58. *Bacterial counts.*—Certified milk shall contain less than 10,000 bacteria per cubic centimeter when delivered. In case a count exceeding 10,000 bacteria per cubic centimeter is found, daily counts shall be made, and if normal counts are not restored within 10 days the certificate shall be suspended.

59. Bacterial counts shall be made at least once a week.

60. *Collection of samples.*—The samples to be examined shall be obtained from milk as offered for sale and shall be taken by a representative of the milk commission. The samples shall be received in the original packages, in prop-

erly iced containers, and they shall be so kept until examined, so as to limit as far as possible changes in their bacterial content.

61. For the purpose of ascertaining the temperature, a separate original package shall be used, and the temperature taken at the time of collecting the sample, using for the purpose a standardized thermometer graduated in the centigrade scale.

62. *Interval between milking and plating.*—The examinations shall be made as soon after collection of the samples as possible, and in no case shall the interval between milking and plating the samples be longer than 40 hours.

63. *Plating.*—The packages shall be opened with aseptic precautions after the milk has been thoroughly mixed by vigorously reversing and shaking the container 25 times.

64. Two plates at least shall be made for each sample of milk, and there shall also be made a control of each lot of medium and apparatus used at each testing. The plates shall be grown at 37° C. for 48 hours.

65. In making the plates there shall be used agar-agar media containing 1.5 per cent agar and giving a reaction of 1.0 to phenolphthalein.

The following is the method recommended by a committee of the American Public Health Association for the making of the media, modified, however, as to the agar content and reaction to conform to the requirements specified in section 65:

1. Boil 15 grams of thread agar in 500 c. c. of water for half an hour and make up weight to 500 grams or digest for 10 minutes in the autoclave at 110° C. Let this cool to about 60° C.
2. Infuse 500 grams finely chopped lean beef for 24 hours with its own weight of distilled water in the refrigerator.
3. Make up any loss by evaporation.
4. Strain infusion through cotton flannel, using pressure.
5. Weigh filtered infusion.
6. Add Witte's peptone, 2 per cent.
7. Warm on water bath, stirring until peptone is dissolved and not allowing temperature to rise above 60° C.
8. To the 500 grams of meat infusion (with peptone) add 500 grams of the 2 per cent agar, keeping the temperature below 60° C.
9. Heat over boiling water (or steam) bath 30 minutes.
10. Restore weight lost by evaporation.
11. Titrate after boiling one minute to expel carbonic acid.
12. Adjust reaction to final point desired +1 by adding normal sodium hydrate.
13. Boil two minutes over free flame, constantly stirring.
14. Restore weight lost by evaporation.
15. Filter through absorbent cotton or coarse filter paper, passing the filtrate through the filter repeatedly until clear.
16. Titrate and record the final reaction.
17. Tube (10 c. c. to a tube) and sterilize in autoclave one hour at 15 pounds pressure or in the streaming steam for 20 minutes on three successive days.

66. Samples of milk for plating shall be diluted in the proportion of 1 part of milk to 99 parts of sterile water; shake 25 times and plate 1 c. c. of the dilution.

The committee on bacterial milk analyses of the American Public Health Association in Part IV of its report presented details with respect to plating apparatus and technique in part as follows:

Plating apparatus.—For plating it is best to have a water bath in which to melt the media and a water-jacketed water bath for keeping it at the required temperature; a wire rack which should fit both the water baths for holding the media tubes; a thermometer for recording the temperature of the water in the water-jacketed bath, sterile 1 c. c. pipettes, sterile Petri dishes, and sterile dilution water in measured quantities.

Dilutions.—Ordinary potable water, sterilized, may be used for dilutions. Occasionally spore forms are found in such water which resist ordinary auto-

clave sterilization; in such cases distilled water may be used or the autoclave pressure increased. With dilution water in 8-ounce bottles calibrated for 99 cubic centimeters * * * all the necessary dilutions may be made.

Short, wide-mouthed "blakes" or wide-mouthed French square bottles are more easily handled and more economical of space than other forms of bottles or flasks.

Eight-ounce bottles are the best, as the required amount of dilution water only about half fills them, leaving room for shaking. Long-fiber nonabsorbent cotton should be used for plugs. It is well to use care in selecting cotton for this purpose to avoid short-fiber or dusty cotton, which give a cloud of lint-like particles on shaking. Bottles * * * should be filled a little over the 99 c. c. * * * to allow for loss during sterilization.

Pipettes.—Straight sides 1 c. c. pipettes are more easily handled than those with bulbs; they may be made from ordinary three-sixteenths inch glass tubing and should be about 10 inches in length.

Plating technique.—The agar after melting should be kept in the water-jacketed water bath between 40° C. and 45° C. for at least 15 minutes before using to make sure that the agar itself has reached the temperature of the surrounding water. If used too warm the heat may destroy some of the bacteria or retard their growth.

Shake the milk sample 25 times, then with a sterile pipette transfer 1 c. c. to the first dilution water and rinse the pipette by drawing dilution water to the mark and expelling; this gives a dilution 1 to 100.

* * * Then with a sterile pipette transfer 1 c. c. to the Petri dish, using care to raise the cover only as far as necessary to insert the end of the pipette.

Take the tube of agar from the water bath, wipe the water from outside the tube with a piece of cloth, remove the plug, pass the mouth of the tube through a flame, and pour the agar into the plate, using the same care as before to avoid exposure of the plate contents to the air.

Carefully and thoroughly mix the agar and diluted milk in the Petri dish by a rotary motion, avoiding the formation of air bubbles or slopping the agar, and after allowing the agar to harden for at least 15 minutes at room temperature, place the dish bottom down in the incubator.

Plating should always be done in a place free from dust or currents of air.

In order that colonies may have sufficient food for proper development 10 c. c. of agar shall be used for each plate.

67. *Determination of taste and odor of milk.*—After the plates have been prepared and placed in the incubator, the taste and odor of the milk shall be determined after warming the milk to 100° F.[1]

68. *Counts.*—The total number of colonies on each plate should be counted, and the results expressed in multiples of the dilution factor. Colonies too small to be seen with the naked eye or with slight magnification shall not be considered in the count.

69. *Records of bacteriologic tests.*—The results of all bacterial tests shall be kept on file by the secretary of each commission, copies of which should be made available annually for the use of the American Association of Medical Milk Commissions.

CHEMICAL STANDARDS AND METHODS.

The methods that must be followed in carrying out the chemical investigations essential to the protection of certified milk are so complicated that in order to keep the fees of the chemist at a reasonable figure, there must be eliminated from the examination those procedures which, whilst they might be helpful and interesting, are in no sense necessary.

For this reason the determination of the water, the total solids and the milk sugar is not required as a part of the routine examination.

70. The chemical analyses shall be made by a competent chemist designated by the medical milk commission.

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[1] Should it be deemed desirable and necessary to conduct tests for sediment, the presence of special bacteria, or the number of leucocytes, the methods adopted by the committee of the American Public Health Association should be followed.

71. *Method of obtaining samples.*—The samples to be examined by the chemist shall have been examined previously by the bacteriologist designated by the medical milk commission as to temperature, odor, taste, and bacterial content.

72. *Fat standards.*—The fat standard for certified milk shall be 4 per cent, with a permissible range of variation of from 3.5 to 4.5 per cent.

73. The fat standard for certified cream shall be not less than 18 per cent.

74. If it is desired to sell higher fat-percentage milks or creams as certified milks or creams, the range of variation for such milks shall be 0.5 per cent on either side of the advertised percentage and the range of variations for such creams shall be 2 per cent on either side of the advertised percentage.

75. The fat content of certified milks and creams shall be determined at least once each month.

76. The methods recommended for this purpose are the Babcock (*a*), the Leffmann-Beam (*b*), and the Gerber (*c*).

(*a*) *Babcock test.*—The Babcock test is based on the fact that strong sulphuric acid will dissolve the nonfatty solid constituents of milk, and thus enable the fat to separate on standing. It can be conducted by any of the Babcock outfits which are purchasable in the market.

"The test is made by placing in the special test bottle 18 grams (17.6 c. c.) of milk. To this is added, from a pipette, burette, or measuring bottle, 17.5 c. c. commercial sulphuric acid of a specific gravity of 1.82 to 1.83. The contents of the bottle are carefully and thoroughly mixed by a rotary motion. The mixture becomes brown and heat is generated. The test bottle is now placed in a properly balanced centrifuge and whirled for 5 minutes at a speed of from 800 to 1,200 revolutions per minute. Hot water is then added to fill the bottle to the lower part of the neck, after which it is again whirled for two minutes. Now, enough hot water is added to float the column of fat into the graduated portion of the neck of the bottle, and the whirling is repeated for a minute. The amount of fat is read while the neck of the bottle is still hot. The reading is from the upper limits of the meniscus. A pair of calipers is of assistance in measuring the column of fat." (Jensen's Milk Hygiene, Leonard Pearson's translation.)

(*b*) *Leffmann-Beam test.*—The distinctive feature is the use of fusel oil, the effect of which is to produce a greater difference in surface tension between the fat and the liquid in which it is suspended, and thus promote its readier separation. This effect has been found to be heightened by the presence of a small amount of hydrochloric acid.

The test bottles have a capacity of about 30 c. c. and are provided with a graduated neck, each division of which represents 9.1 per cent by weight of butter fat.

Fifteen centimeters of the milk are measured into the bottle, 3 c. c. of a mixture of equal parts of amyl alcohol and strong hydrochloric acid added and mixed. Then 9 c. c. of concentrated sulphuric acid is added in portions of about 1 c. c.; after each addition the liquids are mixed by giving the bottle a gyratory motion. If the fluid has not lost all of its milky color by this treatment, a little more concentrated acid must be added. The neck of the bottle is now immediately filled at about the zero point with one part sulphuric acid and two parts water, well mixed just before using. Both the liquid in the bottle and the diluted acid must be hot. The bottle is then placed at once in the centrifugal machine; after rotation from one to two minutes, the fat will collect in the neck of the bottle and the percentage may be read off.

(*c*) *Gerber's test.*—This test is applied as follows: The test bottles are put into the stand with the mouths uppermost; then, with the pipette designed for the purpose, or with an automatic measurer, 10 c. c. of sulphuric acid are filled into the test bottle, care being taken not to allow any to come in contact with the neck. The few drops remaining in the tip of the pipette should not be blown out. Then 11 c. c. of milk are measured with the proper pipette and allowed to flow slowly onto the acid, so that the two liquids mix as little as possible. Finally, the amyl alcohol is added. (It is important to use the reagents in the proper order, which is—sulphuric acid, milk, amyl alcohol. If the sulphuric acid is followed by amyl alcohol and the milk last, then the result is sometimes incorrect.) A rubber stopper, which must not be damaged, is then fitted into the mouth of the test bottle, and the contents are well shaken,

the thumb being kept on the stopper to prevent it coming out. As a considerable amount of heat is generated by the action of the sulphuric acid on the milk, the test bottle should be wrapped in a cloth.

The shaking of the sample must be done thoroughly and quickly, and the test bottle inverted several times, so that the liquid in the neck becomes thoroughly mixed. By pressing in the rubber stopper the height of the liquid can be brought to about the zero point on the scale.

If only a few samples have to be analyzed and the room is warm, the test botttles can be put into the centrifuge without any preliminary heating, otherwise the test bottles must be warmed for a few minutes (not longer) in the water bath at a temperature of 60° to 65° C. When the temperature rises higher than this, say above 70° C., the rubber stopper is liable to be blown out of the test bottle. After the test bottles have been heated they are arranged symmetrically in the centrifuge and whirled for 3 to 4 minutes at a speed of about 1,000 revolutions per minute. When the centrifuge has a heating arrangement attached to it, the preliminary warming is not, of course, necessary. When the test bottles are taken out of the centrifuge, they are again placed in the water bath at a temperature of 60° to 65° C., and left there for several minutes before being read; where the centrifuge is heated, the tubes can be read off as taken from the centrifuge.

By carefully screwing in the rubber stopper, or even by pressing it, the lower limit of the fat column is brought onto one of the main divisions of the scale, and then, by holding the test bottle against the light, the height of the column of fat can be accurately ascertained. The lowest point of the meniscus is taken as the level when reading the upper surface of the fat in a sample of whole milk, and the middle of the meniscus for separated milk.

If the column of fat is not clear and sharply defined, the sample must be again whirled in the centrifuge.

Each division on the scale is equivalent to 0.1 per cent, so it is very easy to read to 0.05 per cent. or, with a lens, to 0.025 per cent. If the number which is read off is multiplied by 0.1, then the percentage quantity of fat in the milk is obtained; e. g., if the number on the scale was 36.5, then the percentage of fat is 3.65. (Milk and Dairy Products, Barthel; translated by Goodwin, p. 71.)

77. Before condemning samples of milk which have fallen outside the limits allowed, the chemist shall have determined, by control ether extractions, that his apparatus and his technique are reliable.

78. *Protein standard.*—The protein standard for certified milk shall be 3.50 per cent, with a permissible range of variation of from 3 to 4 per cent.

79. The protein standard for certified cream shall correspond to the protein standard for certified milk.

80. The protein content shall be determined only when any special consideration seems to the medical milk commission to make it desirable.

81. It shall be determined by the Kjeldahl method, using the Gunning or some other reliable modification, and employing the factor 6.25 in reckoning the protein from the nitrogen.

Kjeldahl method.—Five cubic centimeters of milk are measured carefully into a flat-bottom 800 c. c. Jena flask, 20 c. c. of concentrated sulphuric acid (C. P.; sp. gr., 1.84) are added, and 0.7 gram of mercuric oxid (or its equivalent in metallic mercury); the mixture is then heated over direct flame until it is straw-colored or perfectly white; a few crystals of potassium permanganate are now added till the color of the liquid remains green. All the nitrogen in the milk has then been converted into the form of ammonium sulphate. After cooling, 200 c. c. of ammonia-free distilled water are added, 20 c. c. of a solution of potassium sulphide (containing 40 grams sulphide per liter), and a fraction of a gram of powdered zinc. A quantity of semi-normal HCl solution more than sufficient to neutralize the ammonia obtained in the oxidation of the milk is now carefully measured out from a delicate burette (divided into $\frac{1}{20}$ c. c.) into an Erlenmeyer flask and the flask connected with a distillation apparatus. At the other end the Jena flask containing the watery solution of the ammonium sulphate is connected, after adding 50 c. c. of a concentrated soda solution (1 pound " pure potash " dissolved in 500 c. c. of distilled water and allowed

to settle); the contents of the Jena flask are now heated to boiling, and the distillation is continued for 40 minutes to an hour, until all ammonia has been distilled over.

The excess of acid in the Erlenmeyer receiving flask is then accurately titrated back by means of a tenth-normal standard ammonia solution, using a cochineal solution as an indicator. From the amount of acid used the per cent of nitrogen is obtained; and from it the per cent of casein and albumen in the milk by multiplying by 6.25. The amount of nitrogen contained in the chemicals used is determined by blank experiments and deducted from the nitrogen obtained as described. (Farrington and Woll, Testing Milk and Its Products, p. 221.)

82. *Coloring matter and preservatives.*—All certified milks and creams shall be free from adulteration, and coloring matter and preservatives shall not be added thereto.

83. Tests for the detection of added coloring matter shall be applied whenever the color of the milk or cream is such as to arouse suspicion.

Test for coloring matter.—The presence of foreign coloring matter in milk is easily shown by shaking 10 c. c. of the milk with an equal quantity of ether; on standing, a clear ether solution will rise to the surface; if artificial coloring matter has been added to the milk, the solution will be yellow colored, the intensity of the color indicating the quantity added; natural fresh milk will give a colorless ether solution. (Testing Milk and Its Products, Farrington and Woll, p. 244.)

84. Tests for the detection of formaldehyde, borax, and boracic acid shall be applied at least once each month. Occasionally application of tests for the detection of salicylic acid, benzoic acid, and the benzoates is also recommended.

Test for the detection of formaldehyde.—Five cubic centimeters of milk is measured into a white porcelain dish, and a similar quantity of water added; 10 c. c. of HCl, containing a trace of $Fe_2 Cl_6$, is added, and the mixture is heated very slowly. If formaldehyde is present, a violet color will be formed. (Testing Milk and Its Products, Farrington and Woll, p. 249.)

Test for boracic acid (borax, borates, preservaline, etc.).—One hundred cubic centimeters of milk are made alkaline with a soda or potash solution, and then evaporated to dryness and incinerated. The ash is dissolved in water, to which a little hydrochloric acid has been added, and the solution filtered. A strip of turmeric paper moistened with the filtrate will be colored reddish brown when dried at 100° C. on a watch glass, if boracic acid is present.

If a little alcohol is poured over the ash to which concentrated sulphuric acid has been added, and fire is set to the alcohol, after a little while this will burn with a yellowish-green tint, especially noticeable if the ash is stirred with a glass rod and when the flame is about to go out. (Testing Milk and Its Products, Farrington and Woll, p. 247.)

Test for salicylic acid (salicylates, etc.).—Twenty cubic centimeters of milk are acidulated with sulphuric acid and shaken with ether; the ether solution is evaporated, and the residue treated with alcohol and a little iron-chlorid solution; a deep violet color will be obtained in the presence of salicylic acid. (Testing Milk and Its Products, Farrington and Woll, p. 248.)

Test for benzoic acid.—Two hundred and fifty to five hundred cubic centimeters of milk are made alkaline with a few drops of lime or baryta water, and then evaporated to about a quarter of the bulk. Powdered gypsum is stirred into the remaining liquid until a paste is formed, which is then dried on the water bath. The gypsum only serves to hasten the drying, and powdered pumice stone or sand can be used equally well. When the mass is dry, it is finely powdered and moistened with dilute sulphuric acid and shaken out three or four times with about twice the volume of 50 per cent alcohol, in which benzoic acid is easily soluble in the cold, the fat only being dissolved to a very slight extent or not at all. The acid alcoholic liquid from the various extractions, which contains milk sugar and inorganic salts in addition to the benzoic acid, is neutralized with baryta water and evaporated to a small bulk. Dilute sulphuric acid is again added, and the liquid shaken out with small quantities of ether. On evaporation of the ether, the benzoic acid is left behind in almost pure state, the only impurities being small quantities of fat or ash.

The benzoic acid which is obtained is dissolved in a small quantity of warm water, a drop of sodium acetate and neutral ferric chloride added, and the red precipitate of benzoate of iron indicates the presence of the acid. (Milk and Dairy Products, Barthel; translated by Goodwin, p. 121.)

85. *Detection of heated milk.*—Certified milk or cream shall not be subjected to heat unless specially directed by the commission to meet emergencies.

86. Tests to determine whether such milks and creams have been subjected to heat shall be applied at least once each month.

Detection of heated milk—Storch's method.—Five cubic centimeters of milk are poured into a test tube; a drop of weak solution of hydrogen dioxide (about 0.2 per cent) which contains about 0.1 per cent sulphuric acid, is added, and two drops of a 2 per cent solution of paraphenylendiamin (solution should be renewed quite often), then the fluid is shaken. If the milk or the cream becomes, at once, indigo blue, or the whey violet or reddish brown, then this has not been heated or, at all events, it has not been heated higher than 78° C. (172.5° F.); if the milk becomes a light bluish gray immediately or in the course of half a minute, then it has been heated to 79° to 80° C. (174.2° to 176° F.). If the color remains white, the milk has been heated at least to 80° C. (176° F.). In the examination of sour milk or sour buttermilk, lime water must be added, as the color reaction is not shown in acid solution.

Arnold's guaiac method.—A little milk is poured into a test tube and a little tincture of guaiac is added, drop by drop. If the milk has not been heated to 80° C. (176° F.) a blue zone is formed between the two fluids; heated milk gives no reaction, but remains white. The guaiac tincture should not be used perfectly fresh, but should have stood a few days and its potency have been determined. Thereafter it can be used indefinitely. These tests for heated milk are only active in the case of milks which have been heated to 176° F. or 80° C. (Jensen's Milk Hygiene, Pearson's translation, p. 192.)

Microscopic test for heated (pasteurized) milk—Frost and Ravenel.—About 15 c. c. of milk are centrifuged for 5 minutes, or long enough to throw down the leucocytes. The cream layer is then completely removed with absorbent cotton and the milk drawn off with a pipette, or a fine-pointed tube attached to a Chapman air pump. Only about 2 mm. of milk are left above the sediment which is in the bottom of the sedimentation tube.

The stain, which is an aqueous solution of safranin O, soluble in water, is then added very slowly from an opsonizing pipette. The important thing is to mix stain and milk so slowly that clotting does not take place. The stain is added until a deep opaque rose color is obtained. After standing 3 minutes, by means of the opsonizing pipette, which has been washed out in hot water, the stained sediment is then transferred to slides. A small drop is placed at the end of each of several slides and spread by means of a glass spreader, as in Wright's method for opsonic index determinations.

In an unheated milk the polymorphonuclear leucocytes have their protoplasm slightly tinged or are unstained.

In heated milk the polymorphonuclear leucocytes have their nuclei stained. In milk heated to 63° C. or above, practically all of the leucocytes have their nuclei definitely stained. When milk is heated at a lower temperature the nuclei are not all stained above 60° C. The majority, however, are stained.

87. *Specific gravity.*—The specific gravity of certified milk shall range from 1.029 to 1.034.

88. The specific gravity shall be determined at least each month.

The Quevenne lactodensimeter is recommended for the determination of the specific gravity. It is made like an ordinary aerometer and divided into degrees which correspond to a specific gravity from 1.014 to 1.040, or only 1.022 to 1.038, since by the latter division a greater space is gained between the different degrees without unduly lengthening the instrument. From such a lactodensimeter one can easily read off four decimal places.

The milk the specific gravity of which is to be determined is well shaken and poured into a high glass cylinder of suitable diameter; the aerometer is dropped in slowly, in order to prevent its bobbing up and down. (The bulb should be free from adhering air bubbles.) The figures on the stem are the second and third decimals of the numbers of the specific gravity, so that 34 is to be read 1.034. For this examination, the temperature of the milk must be 15° C.

(60° F.); if it is not, the specific gravity of the milk at 15° C. must be calculated from the specific gravity found and from the temperature, for in milk inspection and analysis this is the standard.

METHODS AND REGULATIONS FOR THE MEDICAL EXAMINATION OF EMPLOYEES THEIR HEALTH AND PERSONAL HYGIENE.

89. A medical officer, known as the attending dairy physician, shall be selected by the commission, who should reside near the dairy producing certified milk. He shall be a physician in good standing and authorized by law to practice medicine; he shall be responsible to the commission and subject to its direction. In case more than one dairy is under the control of the commission and they are in different localities, a separate physician should be designated for employment for the supervision of each dairy.

90. Before any person shall come on the premises to live and remain as an employee, such person, before being engaged in milking or the handling of milk, shall be subjected to a complete physical examination by the attending physician. No person shall be employed who has not been vaccinated recently or who upon examination is found to have a sore throat, or to be suffering from any form of tuberculosis, venereal disease, conjunctivitis, diarrhea, dysentery, or who has recently had typhoid fever or is proved to be a typhoid carrier, or who has any inflammatory disease of the respiratory tract, or any suppurative process or infectious skin eruption, or any disease of an infectious or contagious nature, or who has recently been associated with children sick with contagious disease.

91. In addition to ordinary habits of personal cleanliness all milkers shall have well-trimmed hair, wear close-fitting caps, and have clean-shaven faces.

92. When the milkers live upon the premises their dormitories shall be constructed and operated according to plans approved by the commission. A separate bed shall be provided for each milker and each bed shall be kept supplied with clean bedclothes. Proper bathing facilities shall be provided for all employees on the dairy premises, preferably a shower bath, and frequent bathing shall be enjoined.

93. In case the employees live on the dairy premises a suitable building shall be provided to be used for the isolation and quarantine of persons under suspicion of having a contagious disease.

The following plan of construction is recommened:

The quarantine building and hospital should be one story high and contain at least two rooms, each with a capacity of about 6,000 cubic feet and containing not more than three beds each, the rooms to be separated by a closed partition. The doors opening into the rooms should be on opposite sides of the building and provided with locks. The windows should be barred and the sash should be at least 5 feet from the ground and constructed for proper ventilation. The walls should be of a material which will allow proper disinfection. The floor should be of painted or washable wood, preferably of concrete, and so constructed that the floor may be flushed and properly disinfected. Proper heating, lighting, and ventilating facilities should be provided.

94. In the event of any illness of a suspicious nature the attending physician shall immediately quarantine the suspect, notify the health authorities and the secretary of the commission, and examine each member of the dairy force, and in every inflammatory affection of the nose or throat occurring among the employees of the dairy, in addition to carrying out the above-mentioned program, the attending physician shall take a culture and have it examined at once by a competent bacteriologist approved by the commission. Pending such examination, the affected employee or employees shall be quarantined.

95. It shall be the duty of the secretary, on receiving notice of any suspicious or contagious disease at the dairy, at once to notify the committee having in charge the medical supervision of employees of the dairy farm upon which such

disease has developed. On receipt of the notice this committee shall assume charge of the matter, and shall have power to act for the commission as its judgment dictates. As soon as possible thereafter, the committee shall notify the commission, through its secretary, that a special meeting may be called for ultimate consideration and action.

96. When a case of contagious disease is found among the employees of a dairy producing certified milk under the control of a medical milk commission, such employee shall be at once quarantined and as soon as possible removed from the plant, and the premises fumigated.

When a case of contagion is found on a certified dairy it is advised that a printed notice of the facts shall be sent to every householder using the milk, giving in detail the precautions taken by the dairyman under the direction of the commission, and it is further advised that all milk produced at such dairy shall be heated at 145° F. for 40 minutes, or 155° F. for 30 minutes, or 167° F. for 20 minutes, and immediately cooled to 50° F. These facts should also be part of the notice, and such heating of the milk should be continued during the accepted period of incubation for such contagious disease.

The following method of fumigation is recommended:

After all windows and doors are closed and the cracks sealed by strips of paper applied with flour paste, and the various articles in the room so hung or placed as to be exposed on all sides, preparations should be made to generate formaldehyde gas by the use of 20 ounces of formaldehyde and 10 ounces of permanganate of potash for every 1,000 cubic feet of space to be disinfected.

For mixing the formaldehyde and potassium permanganate a large galvanized-iron pail or cylinder holding at least 20 quarts and having a flared top should be used for mixing therein 20 ounces of formaldehyde and 10 ounces of permanganate. A cylinder at least 5 feet high is suggested. The containers should be placed about in the rooms and the necessary quantity of permanganate weighed and placed in them. The formaldehyde solution for each pail should then be measured into a widemouthed cup and placed by the pail in which it is to be used.

Although the reaction takes place quickly, by making preparations as advised all of the pails can be "set off" promptly by one person, since there is nothing to do but pour the formaldehyde solution over the permanganate. The rooms should be kept closed for four hours. As there is a slight danger of fire, the reaction should be watched through a window or the pails placed on a noninflammable surface.

97. Following a weekly medical inspection of the employees, a monthly report shall be submitted to the secretary of the medical milk commission, on the same recurring date by the examining visiting physician.

The following schedule, filled out in writing and signed by himself, is recommended as a suitable form for the attending physician's report:

This is to certify that, on the dates below indicated, official visits were made to the ——— dairy, owned and conducted by ——— of ——— (indicating town and State), where careful inspections of the dairy employees were made.

(*a*) Number and dates of visits since last report. ———.

(*b*) Number of men employed on the plant. ———.

(*c*) Has a recent epidemic of contagion occurred near the dairy, and what was its nature and extent? ———.

(*d*) Have any cases of contagious or infectious disease occurred among the men since the last report? ———.

(*e*) Disposition of such cases. ———.

(*f*) What individual sickness has occurred among the men since the last report? ———.

(*g*) Disposition of such cases. ———.

(*h*) Number of employees now quarantined for sickness. ———.

(*i*) Describe the personal hygiene of the men employed for milking when prepared for and during the process of milking. ———.

(*j*) What facilities are provided for sickness in employees? ———.

(*k*) General hygienic condition of the dormitories or houses of the employees. ———.

(*l*) Suggestions for improvement. ———.

(*m*) What is the hygienic condition of the employees and their surroundings? ———.

(*n*) How many employees were examined at each of the foregoing visits? ———.

(*o*) Remarks.

———— ————,
Attending Physician.

Date, ———.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 2

Contribution from the Bureau of Soils, Milton Whitney, Chief.
December 27, 1913.

THE FISH-SCRAP FERTILIZER INDUSTRY OF THE ATLANTIC COAST.

By J. W. Turrentine,
Scientist in Soil Laboratory Investigations.

PURPOSE OF THE INVESTIGATION.

The present investigation forms a part of the general plan of the Bureau of Soils to survey the Nation's assets in fertilizer materials. The three elements which constitute the essential ingredients of most of the artificial fertilizers compounded and marketed in this country are phosphorus, potassium, and nitrogen. The former two occur in nature as the salts of phosphoric acid and potassium, respectively. The investigation of the Nation's resources in these, therefore, has had to do with the examination of known deposits and exploration for new. In this connection and under the direction of the Bureau of Soils, the phosphate fields of South Carolina, Tennessee, Florida, Utah, Idaho, Arkansas, and Kentucky have been surveyed by W. H. Waggaman;[1] the desert basins and certain saline lakes of Oregon, California, Arizona, New Mexico, and Nevada have been examined by E. E. Free,[2] in collaboration with J. G. Young and A. R. Merz, to determine the occurrence of potassium salts therein; W. H. Ross[3] has studied the decomposition of the feldspars with a view to the liberation therefrom of the combined potash; Waggaman[4] has investigated the decomposition of alunite and the extraction of potash therefrom; W. C. Crandall,[5] G. B. Rigg,[6] and F. M. McFarland,[7] have surveyed certain of the kelp groves of the Pacific coast to determine the amounts of those potash carriers available, while the writer has determined the potash content of a number of these sea plants collected from the coast of California, Washington, and Alaska;[8] the behavior of kelps when subjected to destructive

[1] Buls. Nos. 69, 76, and 81, Bureau of Soils, U. S. Dept. of Agr.
[2] Circ. No. 61, Bureau of Soils, U. S. Dept. of Agr., and a manuscript not yet published.
[3] Circ. No. 71, and a manuscript not yet published.
[4] Circ. No. 70, Bureau of Soils, U. S. Dept. of Agr.
[5] "Fertilizer Resources of the United States." Sen. Doc. 190, 62d Cong., 2d sess., 1912; Appen. N, p. 209.
[6] Ibid., Appen. L, p. 179.
[7] Ibid., Appen. M, p. 194.
[8] Turrentine, ibid., Appen. P, p. 217, The Composition of Kelps.

distillation has been studied in the experimental laboratories of Mr. John W. Hornsey, consulting engineer, 49 Wall Street, New York, with a view to the possible employment of such a process for the extraction of potash and useful by-products;[1] the writer,[2] in collaboration with W. C. Phalen, of the United States Geological Survey, and W. H. Ross, A. R. Merz, R. F. Gardener, and J. A. Cullen, of this bureau, has studied the composition of the salines, brines, and mother liquors from the principal salt-producing areas of the United States, of natural subterranean brines from various salt wells and oil and gas wells of the various sections of the country explored and prospected for the latter two, of brines and salt crusts from desert sinks or playas, and of mother liquors from certain solar refineries of ocean brine on the Pacific coast, with a view to their potash content and their utilization as a source of potassium salts; Free[3] has investigated certain desert areas where nitrates have been found; Waggaman has studied the peat beds of Florida, regarded as a possible source of combined nitrogen and of value as a filler for manufactured fertilizers, and has reported[4] on the production of ammonium sulphate.

Nitrogenous compounds, of fertilizer interest, to a greater extent than those of phosphorus and potassium, are of artificial derivation, though they likewise are obtained in natural deposits. The investigation has had to do further with the examination of those operations and processes which lead to the production of such nitrogenous compounds, generally as by-products, as may be used in the preparation of fertilizers.

The information sought in the present study has been in part statistical, to determine the history of the industry in terms of equipment and output, and its present and proposed development. In addition, information has been sought regarding the particulars in which the processes now in vogue could be improved, the means whereby the industry could be put on a more secure economic basis, and its possibilities for enlargement. The Department of Agriculture has been organized primarily to effect the advancement of the agricultural interests of the Nation, and it is believed that in advancing the interests of the manufacturers of fertilizers and in helping them to increase their output and to reduce the cost of manufacture, the interests of the farmers are enhanced. In other words, the interests of the manufacturer and of the purchaser of fertilizer

[1] Turrentine, Proc. 8th Internat. Cong. Appl. Chem., 1912, vol. 15, p. 313.

[2] Composition of the Salines of the United States, J. Ind. Eng. Chem., 4, 828; ibid., 4, 885 (1912); ibid., 5, 19 (1913); Bul. No. 94, Bureau of Soils, U. S. Dept. Agr. (1913); Proc. 8th Internat. Cong. Appl. Chem., 1912, vol. 15, p. 319.

[3] Circ. No. 62, Bureau of Soils, U. S. Dept. Agr.

[4] Sen. Doc. 190, Appen. E, p. 119.

are closely allied. The accumulation of full information concerning the fish-scrap industry is essential as a preliminary step toward the furtherance of that industry.

HISTORICAL.

The fish-scrap industry may be said to have had its inception even before the advent of white settlers on the American Continent. Practices were in vogue which led directly to that industry. The custom existed among the Indians of New England of fertilizing their crops by means of fish. It is stated that for fertilizing corn, one or two fish were placed in each corn hill. This practice was adopted by the colonists, and extended to the scattering of fish broadcast over the fields. In later years, where the latter practice was carried to an extreme, it was found that it resulted in serious detriment to the soil because of the accumulation therein of the undecomposed oil from the fish. Later, it was found that the oil could be readily removed from the fish without impairing their usefulness for fertilizer purposes. This was accomplished by placing the fish in hogsheads or barrels, covering with water, compressing with weighted boards, and allowing to stand for the putrefaction of the fish to release the oils. The oil rose to the surface and was skimmed off. The residue was spread upon the land. The oil thus obtained was put to various uses in the domestic enterprises of the farms. It was soon found that cooking the fish released the oils as effectually as disintegration through putrefaction, and very much more quickly and less offensively.

For the farmers living near the shore it became a part of the year's routine to prepare fish scrap and, incidentally, oil for the year's supply. As the spring was regarded as the best time for the application of this fertilizer, a few weeks of the spring were devoted to fishing and rendering. The apparatus necessary, seines and pots, often were owned and operated in common.

In time pot cooking was superseded by the adoption of steam cookers; the first factory for cooking by steam was a small one put up near Portsmouth, R. I., in 1841.[1]

In 1850 Daniel Wells built a factory on Shelter Island, N. Y. That was the first factory of considerable size on the coast, and the quantity of fish handled amounted to 2,000,000 or 3,000,000 in number annually. In 1853 Mr. Wells built a new factory on Shelter Island and the old one was removed to Groton, Conn., being the first steam factory in that State. The first factory in Maine was put up in 1863 at South Bristol, and in 1866 11 factories were built in Maine. In 1869 the factory at South Bristol, Me., was removed to Fair Port, Va., and was the first factory in that State.[2]

The subsequent development of the industry was marked by the introduction of the purse seine,[3] facilitating the capture of fish in

[1] Aquatic Products in Arts and Industries, Charles H. Stevenson. Appen. to Rept. of U. S. Fish Comm., 1902, pp. 177–279.

[2] Quoted from Stevenson, loc. cit.

[3] Further discussed under Technology.

greatly increased numbers, and the adoption of presses for separating the oil and increasing the yield of it, in the place of the older method of depending on the lighter specific gravity of the oil to effect a separation. Hand presses were introduced in 1856 by Mr. Charles Tuthill, of the Wells factory on Shelter Island. In 1858 hydraulic power was introduced as a substitute for hand power. In more recent years, however, steam presses have been introduced with such success that they are to be found in practically every new factory, and they are rapidly being installed in the old factories to take the place of those operated by hydraulic power. A further rapid development of the industry was made possible through the substitution of steamers for sailing vessels; this rendered the fishermen independent of the winds in searching for and overtaking the schools of fish and in returning to the factories with their cargoes. In spite of this self-evident advantage, it has been only within the last few years that the last sailboats of considerable size, fishing for menhaden, have been equipped with auxiliary engines.

The so-called "floating factory" was designed to obviate loss of time by the fishing boats in going back and forth between the factories and the fishing grounds, the idea being to carry the factory to the fish instead of taking the fish to the factory. Introduced in 1876, a number had been constructed and were in operation in 1880. They consisted of boats of various sorts equipped with the apparatus for rendering the fish, such as boilers, cooking vats, and presses. The lack of storage room for the products, the difficulty of loading and unloading at sea, and other considerations brought about their abandonment. The latest attempt to apply the floating-factory idea was in 1911, when a steamer of 5,000 tons was equipped with a complete set of the modern automatic apparatus for producing dried scrap.[1]

A form of fish-scrap fertilizer which could be shipped long distances or stored was prepared first by drying the scrap from the presses on platforms. Here the material was spread to dry and was manipulated in the meantime by hand rakes or hoes to expose fresh surfaces. In certain instances the platform drier is still in use, notably in those neighborhoods where the odor and smoke from hot-air driers develops a hostile attitude of neighboring communities. However, the dispatch and convenience with which scrap may be dried in the artificial driers have led to their almost universal adoption.

The business continued to expand until it reached its high-water mark in 1884, when 858,592,691 fish were caught, yielding 3,722,927 gallons of oil and 68,863 tons of scrap, valued at $2,800,000. Since that time great improvements have been made in the methods of the industry, but owing to the low price of oil and scrap, resulting from the competition with other products, the profits have not been so great, and many factories have been dismantled. The largest catch

[1] For a description of this plant cf. section on Technology, p. 32.

of fish in any one year, according to the figures of the United States Menhaden Oil and Guano Association, was 858,592,691, taken in 1884; the smallest was 223,623,750, secured in 1892, and the average catch during the last 30 years approximates 500,000,000 annually. The incomplete returns for 1902 indicate that the catch exceeded 900,000,000, a greater quantity than for any previous year.[1]

The literature dealing with the fish-scrap industry is confined almost altogether to a small number of reports, prepared through State or Federal initiative. Conspicuous among these are two valuable reports by G. Brown Goode, on The Natural and Economic History of the American Menhaden,[2] and by Charles H. Stevenson, on Aquatic Products in Arts and Industries,[3] respectively. The present writer has drawn freely from these articles for supplementary information used in the present paper.

PRESENT STATUS.

At present there are about 40 factories on the Atlantic seaboard which manufacture fish scrap. This number includes only those whose main output is fish scrap and fish oil. Thus are excluded those whose output in fish scrap is small and an entirely secondary matter, such as the concerns which manufacture glue from cod and other fish refuse. While residues from their cookers are sold for fertilizers and are essentially fish scrap, their output in scrap is too small to accord them more than mere mention in this discussion.

Of this number of plants, the distribution by States is as follows: Maine, 1; Connecticut, 2; New York, 3; New Jersey, 5; Delaware, 2; Virginia, 21; North Carolina, 11; and Florida, 1; from which it is seen that the Chesapeake Bay region in point of number of plants is the center of the industry.

In the following table are listed the factories of the principal producers of fish scrap and their location:

TABLE I.—*List of factories of the principal producers of fish scrap on the Atlantic coast and location.*

Name of concern.	Location of plant.
Maine:	
Deep Cove Manufacturing Co	Deep Cove, Me.
Connecticut:	
Niantic Menhaden Oil & Guano Co	South Lyme, Conn.
Wilcox Fertilizer Co	Mystic, Conn.
New York:	
Atlantic Fertilizer & Oil Co	Promised Land, N. Y.
Neptune Fishing Co	Do.
Triton Oil Co	Do.
New Jersey:	
Atlantic Fisheries Co	Tuckerton, N. J.
Fifield Fish Oil and Fertilizer Co	Leesburg, N. J.
McKeever Bros	Tuckerton, N. J.
Monmouth Oil & Guano Co. (successors to the Vernon S. Vail Co.).	Port Monmouth, N. J.
New York & New Jersey Oil & Guano Co	Do.

[1] Stevenson, loc. cit. [2] U. S. Fish Comm. Rept., 1877, pp. 1–523
[3] U. S. Fish Comm. Rept., 1902, pp. 177–352.

TABLE I.—*List of factories of the principal producers of fish scrap on the Atlantic coast and location*—Continued.

Name of concern.	Location of plant.
Delaware:	
Delaware Fish Oil Co	Lewes, Del.
Lewes Fisheries Co	Do.
Virginia:	
Bellows & Squires	Ocran, Va.
Coan River Oil & Guano Co	Lewisetta, Va.
Carters Creek Fish & Guano Co	Irvington, Va.
Davis Packing Co	Reedville, Va.
Davis Palmer Co.[1]	Palmel, Va.
Dennis Fish & Oil Co	Cape Charles, Va.
The Douglas Co	Reedville, Va.
The Edwards Co	Do.
The Edwards & Reed Co	Do.
The Eubanks-Tankard Co	Kilmarnock, Va.
Indian Creek Fertilizer Co	Byrdton, Va.
McNeal Edwards Co	Reedville, Va.
Menhaden Oil & Guano Co	Harborton, Va.
Morris Fisher Co	Reedville, Va.
Norfolk Fisheries Corporation	Seaford, Va.
Seaboard Oil & Guano Co. (successors to Haynie & Snow)	Reedville, Va.
Seaboard Oil & Guano Co. (successors to Hinton, Tolson Oil & Guano Co.)	Mila (near Reedville), Va.
Seaboard Oil & Guano Co.[1]	Chincoteague Island, Va.
Stringfellow Operating Co.[2]	Harveys Wharf, Va.
Wharton Fisheries Co., (Inc.)	Ocran, Va.
Taft Fish Co	Taft, Va.
North Carolina:	
Beaufort Fish Scrap & Oil Co	Beaufort, N. C.
Chadwick & Caffrey	Do.
C. P. Dey	Lenoxville Point (near Beaufort), N. C.
Doan & Bartlett	Beaufort, N. C.
Ocean Fisheries Co	Wilmington, N. C.
Nat. Russell	Swansboro (near Beaufort), N. C.
R. W. Taylor	Morehead City, N. C.
Taylor & Guthery	Do.
Charles S. Wallace	Do.
Do	Smyrna (near Beaufort), N. C.
A. T. Willis	Williston (near Beaufort), N. C.
Florida:	
Southern Menhaden Co	Fulton, Fla.

[1] In course of erection, 1912. [2] Receivers for Menhaden Fishing Corporation.

The output, by States, during the year 1912, is given in Table II. The figures given in the compilation for the most part were obtained on or before November 1. While the catch for the balance of the season was estimated in certain instances, it is believed that the figures here given may be low.

TABLE II.—*The output of fish scrap, by States, 1912.*

State.	Acid.	Dry.	State.	Acid.	Dry.
	Tons.	*Tons.*		*Tons.*	*Tons.*
Maine	100	256	Delaware	6,312	500
Connecticut	1,500	6,500	Virginia	.....	34,000
New York	19,800	.....	North Carolina	.....	7,250
New Jersey	530	1,500	Florida	.....	160

Announcement is made of the recent organization of the following companies to engage in the fish-scrap industry: The South Coast Oil & Fertilizer Co., to operate at Port Arthur, Tex., and E. E. Saunders & Co., to operate at Pensacola, Fla.

In Table III are given the statistics of the fish-scrap industry for the years 1873–1898, inclusive, taken from Stevenson's report.[1] Since the dissolution of the United States Menhaden Oil and Guano Association the statistics of the industry have not been made available.

TABLE III.—*Statement of the extent of the menhaden industry of the United States in each year from 1873 to 1898, inclusive, according to the returns of the United States Menhaden Oil and Guano Association.*

Year.	Factories.	Men employed.	Vessels employed.		Capital invested.	Fish received.	Oil made.	Scrap made.	
			Steam.	Sail.				Dried.	Crude or acidulated.
					Dollars.		*Gallons.*	*Tons.*	*Tons.*
1873	62	2,306	20	300	2,388,000	397,700,000	2,214,800	.....	36,299
1874	64	2,438	25	283	2,500,000	492,878,000	3,372,847	.....	50,976
1875	60	2,633	39	304	2,650,000	563,327,000	2,681,482	.....	53,625
1876	64	2,758	46	320	2,750,000	512,450,000	2,992,000	.....	51,245
1877	56	2,631	63	270	2,047,612	587,642,125	2,426,589	5,700	49,744
1878	56	3,337	64	279	2,350,000	767,779,250	3,809,233	19,377	64,342
1879	60	2,296	81	204	2,502,500	637,063,750	2,258,901	29,563	37,496
1880	79	3,261	82	366	2,550,000	776,875,000	2,034,940	25,800	19,020
1881	97	2,805	73	286	2,460,000	454,192,000	1,266,549	25,027	7,592
1882	97	2,313	83	212	2,338,500	346,638,555	2,021,316	17,552	10,029
1883	78	2,427	69	136	2,651,000	613,461,776	2,166,320	34,216	10,920
1884	52	2,114	59	157	1,534,756	858,592,691	3,722,927	58,433	10,430
1885	50	2,064	78	84	1,314,500	479,214,415	2,346,319	33,910	7,225
1886	26	1,154	45	74	1,234,000	283,106,000	1,805,544	14,597	4,298
1887	28	2,499	46	38	1,000,000	333,564,800	2,273,566	17,262	5,368
1888	24	3,568	45	42	3,000,000	439,388,950	2,051,128	15,638	12,406
1889	29	4,400	46	84	2,500,000	555,319,800	3,327,030	24,359	25,859
1890	28	4,368	52	27	2,500,000	533,686,156	2,939,217	20,339	21,173
1891	27	2,985	54	13	1,775,000	355,138,873	1,946,642	12,608	15,069
1892	29	2,002	55	10	1,756,000	223,623,750	1,329,644	8,400	10,815
1893	33	2,235	57	27	1,721,000	366,406,625	1,269,002	13,150	15,465
1894	44	2,356	56	28	2,000,000	533,361,900	1,999,506	20,057	27,582
1895	42	2,276	48	35	1,600,000	461,747,000	1,767,754	18,682	21,965
1896	35	2,115	53	38	1,376,500	401,425,800	1,741,530	14,280	21,484
1897	41	2,750	60	45	1,871,000	584,302,930	2,147,113	18,430	34,372
1898	40	2,470	51	20	2,500,000	542,500,000	2,450,000	17,360	34,120

THE MENHADEN.

NAMES.

The menhaden, *Brevoortia tyrannus*, is commonly known on the various sections of the Atlantic coast by various popular names. In Maine it is called the "pogy," though sometimes the "menhaden"; likewise in Massachusetts it is spoken of as the "pogy" and the "menhaden," and occasionally as the "hardhead." In Rhode Island it is known as the "menhaden," while in Connecticut the names "bony fish" and "white fish" have been applied to it. In New York and New Jersey it is designated as the "mossbunker"; and as one passes southward the names "alewife," or "old wife," and "bug fish" (on account of a parasitic crustacean found in its mouth in certain regions) are encountered, until North Carolina is reached, when the names "fatback" and "shad" prevail. The name menhaden sup-

[1] Loc. cit.

posedly had its origin in the Indian word "munnawhatteaug," applied to that fish, as well as to others, which means "fertilizer" or that which "manures."[1] The other names for the most part are likewise descriptive.

DESCRIPTION.

For a detailed description of anatomical characteristics and measurements of the *Brevoortia tyrannus* see the report by Goode, referred to above. The following description of the appearance of the adult fish is quoted from the same author:[2]

> The adult menhaden is a most beautiful fish. Its color is pearly opalescent, like that of the cyprinoid fishes from which the commercial "essence d'orient," or liquid pearl, used by artists, and in the manufacture of paste jewelry, is prepared. Each scale has all the beauty of a fine pearl, and the reflections taken from the mailed side of a fish just taken from the water are superb. The scales of the back and of the top of the head are of a purplish blue. The blotch of black upon the scapular region, just above the origin of the pectoral, is very constant, although I have seen fish in which it did not occur. Many, especially of the older and fatter ones, have a number of irregular, roundish, blue-black blotches upon the sides and flanks. The young fish are not so brilliantly colored, and, in general appearance, resemble the young of shad.

Other species of the genus Brevoortia are found in the Gulf of Mexico and on the shores of Brazil.

From a study of the young of related fish, it appears probable that the menhaden requires three or four years in which to attain full growth. At the end of the first year they are from 3 to 5 inches in length; at the end of the second, 7 to 10 inches; the third, 12 to 14 inches; and the full grown fish is from 16 to 18 inches in length. The largest specimen of menhaden recorded was 20 inches in length.

OCCURRENCE AND MOVEMENTS.

The geographical limits of the northern menhaden seem to be the Bay of Fundy at the north and the southern coast of Florida at the south. It can be expected to make its appearance annually in the coastal waters of all the States from Maine to Florida (between the parallels 25° and 45° north). To the landward it is limited by brackish water; oceanward, by the Gulf stream.

The menhaden is regarded universally by fishermen as a migratory fish in the sense that it migrates northward in the spring and southward in the fall. The matter of its migration has been studied by Goode. Available information from numerous sources, as well as from a priori considerations, has been brought to bear on this interesting question.

Two sorts of piscatorial migration are recognized, equatorial and abatic. The former takes a northern and southern direction, like

[1] Quoted from Goode, U. S. Fish Comm. Rept. 1877, 11.
[2] Goode, loc. cit. Cf. p. 33.

that of the migration of birds; the latter may be described as an up and down migration, or what amounts to the same thing, an off and on shore migration. The former is seasonal, while the latter may be seasonal, diurnal, or irregular. Fish migrate for various reasons: (1) To find water of an agreeable temperature and depth; (2) to find water of an agreeable temperature and depth in which food can be acquired; and (3) to spawn. By noting the temperature of the water of the various regions in which the menhaden have shown themselves, at the time of their appearance and of their departure, correlating figures have been obtained which are taken to indicate the extremes of temperature agreeable or bearable to the menhaden. The temperature thus indicated as most agreeable is 60° to 70° Fahrenheit. Where the temperature of the water in the spring reaches 50° F., the fish are likely to appear; and when it falls to that temperature in the autumn, they are equally apt to disappear. Apparent exceptions to the latter have been observed; it is believed, however, that the exceptional cases were caused by the detentions of the fish against their will by the contour of the coast line, or other such causes. This is taken as the lower limit of temperature bearable to the menhaden, while the upper limit is believed to be 75° to 80° F. Thus, the coolness of the night, or a cold wind lowering the temperature of the surface water, causes the schools to disappear beneath the surface.

Sensitiveness to temperature change, hypothesized for the menhaden, is not peculiar to that fish. On the contrary, the supposition of this sensitiveness is based on the definite knowledge that that characteristic is possessed by other fish.

Since menhaden disappear from northern waters during the winter to return again during the summer, it becomes necessary to account for their movements in the interim. Three courses are open to them: (*a*) To migrate to southern waters; (*b*) to hibernate in waters of great depth and low temperature; (*c*) to migrate abatically, or offshore, until waters of congenial temperature are reached.

The first suggestion is in conformity with the prevailing beliefs of the fishermen. They picture the northern migration as a movement of the whole body of fish, swimming at a great rate of speed, feeding as they advance and increasing in fat, the larger and stronger pushing on farther north while the smaller and weaker are left behind and tarry in the more southern regions; that in the fall they return, growing thinner as they advance, due to the development of the roe ("the fat all goes into the roe"), and that they remain south during the winter. This belief is logical to the extent at least that during the spring the schools frequently are seen actually swimming north and in the fall south. And it is known that they are to be seen in Florida waters during the winter.

However, this theory is scarcely tenable when it is remembered that the menhaden are never seen south of the southernmost point of Florida, and that during the winter they are never seen north of northernmost Florida. So the intervening stretch of coastal waters must accommodate the myriads of fish forming the immense schools visible farther north during the summer. The fact that there is only one fish scrap factory on the Atlantic coast side of Florida is abundant evidence that this is not the winter retreat of the Atlantic menhaden. The Florida menhaden, besides, possess different characteristics from the northern. They are unmistakably different in size and coloration. In fact, the fish caught on the different sections of the coast are peculiar to those sections; those in certain sections are infested with certain parasites not found on those from other sections. This fact is almost incontestable evidence that the fish thus characterized could not have been a part of a general migratory school the other members of which being entirely free from the parasites.

The size of the fish, as well as other characteristics, varies, those of a certain size being peculiar to a certain part of the coast. Roughly the largest fish, averaging about 12 inches in length, are found in the waters off the New England States; those taken in the Long Island region are about 10 inches; those off New Jersey and Delaware about 9 inches; those in the Chesapeake Bay region about 8 inches; and those found below Cape Hatteras about 6 to 7 inches in length.[1] It does not seem in the least to trouble the adherents of the coastal migration theory that the large fish characteristic of the New England coast always escape capture as they pass the southern coast twice a year.

With regard to the second hypothesis it should be said that in those instances where it is known definitely that fish hibernate in a state of torpidity it is generally where that course of action is forced upon them. Thus it is restricted to fish in those bodies of water which are thoroughly chilled during the winter. Their torpidity is induced by the low temperature. It is difficult to believe that a fish in the ocean, where all agreeable temperatures are to be had, would willingly search out a spot, at some great depth and corresponding pressure, where the temperature was sufficiently chilling to induce torpidity and where a radical change in habits would have to be undergone. In addition, a fish once rendered torpid in the depths of the ocean would remain there, as the conditions there would be permanent.

The third alternative, the assumption that the fish, while migrating equatorially to a limited extent during the season of warm coastal water, migrate abatically for their winter's sojourn in the warmer

[1] Hathaway, Bull. Bureau of Fisheries, 1908, Part I, p. 271.

water lying oceanward, appears more plausible. An exploration of ocean temperatures has shown that there are strata lying offshore and at a depth of 50 to 100 fathoms whose temperature is about 50° to 55° F. It is suggested that the fish swimming oceanward at the beginning of cold weather, and being driven downward by the chilled surface water, strike the warm strata and are held there during the winter by the surrounding barriers of colder strata. In the spring, with the removal of these barriers, they swim shoreward again to their accustomed feeding grounds. This accounts, furthermore, for their prompt appearance offshore as soon as the water there reaches a temperature of 50° F. Their emaciated condition in the spring would show the scarcity of food in the region of their winter's stay. Indeed, they are so "thin" that a thousand spring fish frequently yields only a half gallon of oil as compared with 10 to 15 gallons of oil produced by an equal number of fall fish.[1]

HABITS.

The menhaden swim in schools made up almost always of large numbers. Schools have been reported 20 miles in length, but this size is exceptional. The fish in the schools are densely massed, not only side by side but one above the other. They produce a rippling in the water which is discoverable at a distance and which betrays the presence of the schools to the fishermen. Their location is indicated also by flocks of gulls which follow the schools.

The schools frequent the larger bays and inlets such as Chesapeake and Delaware Bays and Long Island Sound; these and other similar waters formerly constituted the main fishing grounds. But they are found also in deeper waters opposite the entrances to bays and sounds and off promontories. Thirty years ago it was their habit also to ascend rivers as far as the brackish water would permit. This they no longer do to a conspicuous degree. While they are not so much in evidence perhaps near the shore, there is no evidence that they are decreasing in numbers. They appear to be the most numerous fish on the Atlantic coast. The maintenance of the catch year after year, however, can not be taken as proof that the menhaden is not decreasing in numbers, unless it be shown that the maintenance of the catch is not the result of increased skill in fishing.

FOOD.

The examination of the stomach contents of a large number of menhaden at various times and from numerous localities has revealed only large quantities of dark material, resembling the silt such as is found on the bottom in sheltered and quiet water near river mouths.

[1] "Occasionally fat fish are taken in the spring, indicating that food is not always absent from the winter abode of the menhaden." Kendall, Bureau of Fisheries. Private communication.

An examination of bottom mud has shown it to contain large quantities of living and dead microorganisms, making up more than half of its bulk. This is supposed to constitute the food of the bivalves and other aquatic animals of similar habits. It has been shown by Peck [1] that the menhaden is provided with a mechanism, situated upon the anterior edge of the gill arches, and known as "gill rakers," by means of which it is able to strain out from the water in which it swims the microorganisms which live there. "These minute organisms furnish directly the food of the menhaden. * * * The whole food supply of this fish is obtained by filtering out from the surface stratum of water the organic life there suspended." [2]

SPAWNING.

Very little is known definitely of the breeding habits of the menhaden. Numerous theories are entertained by the fishermen. Some confess ignorance; others believe they spawn in southern rivers; others, that they spawn "on the edge of the Gulf stream."

The large number of young which appear on the coast of North Carolina in early spring indicate the nearness of the spawning ground to that region and of the spawning season to that time. The absence of a developed roe in the fish of that region in the summer and its appearance only in late fall and winter mark the time of spawning there as the winter or early spring. As the fish have disappeared from the coast at that time, except along the Carolinas and Florida, the spawning ground must be on the shores of either the Carolinas or Florida. Evidence is lacking that they enter the rivers at this time in sufficient numbers to represent a concerted movement toward a spawning ground, such as is shown by other fish, occurring in much smaller numbers than the menhaden, in the spawning season.

Hathaway [3] states that he has examined many hundreds of menhaden caught between Cape Lookout, N. C., and Georgetown, S. C., from the 20th of November to the 10th of December, among which there was not one that did not show a roe development such as to indicate that it would spawn within 30 to 60 days.

Smith has shown that menhaden have been taken on the coast of North Carolina in November from which spawn was running showing conclusively that menhaden may spawn in November,[4] and states that in spring and early summer the menhaden spawns in abundance on the northern part of the middle Atlantic and the southern part of the New England coast, and in late autumn and early winter on the southern part of the middle Atlantic and the northern part of the south Atlantic coast.

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[1] "On the Food of the Menhaden," Bull. U. S. Fish Commission, 1893, p. 113.
[2] Peck, loc. cit. cf. p. 114.
[3] "The Menhaden Industry," American Fertilizer, 38, 44 (1913).
[4] Smith, Hugh M., Fishes of North Carolina, N. C. Geol. and Econ. Survey, p. 132.
[5] Hathaway, Bull. Bureau of Fisheries, 1908, Pt. I, cf. pp. 277–278.

In this connection the following statement, quoted from Smith,[1] is of great interest:

> By the first week in November the development of the reproductive organs had progressed so far that the approach of the spawing period appeared to be imminent in the fish caught close to land on the ocean shores of Maryland, Virginia, and North Carolina. On November 6 large hauls of menhaden off the Maryland coast contained fish from 9 to 12 inches long that were very nearly ripe, and on November 7, 9, and 13 small quantities of eggs or milt could be forced by gentle pressure from most of the fish examined, taken on the same grounds. On November 13 a female menhaden 11 inches long, caught in a school off the Virginia coast appeared to be spent, November 16 a similar specimen with shriveled and empty ovaries was found among some almost ripe fish on the North Carolina coast. In the latter part of November eggs or milt could be forced by gentle pressure from nearly all menhaden caught south of Cape Henry.

Investigations, carried on by the Bureau of Fisheries during the summer of 1895, extending from June 29 to August 6, showed that the menhaden were spawning in the waters off the coast of Maine during that period. It is the belief of the fishermen of that region that they spawn throughout the summer.

PREDATORY ENEMIES.

The immense and clumsy schools of menhaden, swimming in open water, fall an easy prey to all the large carnivorous aquatic animals frequenting the Atlantic coastal waters. Beginning with the whales, the largest of these, the destruction by them in former years was considerable, a single mouthful of a whale representing, perhaps, a hogshead of fish. The larger sharks attack them, but destruction by them is slight when compared with that of the dogfish moving and attacking in schools. Other fish, such as the horse mackerel, the pollock, the striped bass, the sea trout, the swordfish, the bayonet-fish, and, possibly, the codfish, are counted among their destructive enemies. The bluefish and the bonito, however, are regarded as the greatest destroyers of the menhaden, as they not only consume great numbers of them, but wantonly cut and destroy countless others. A school of bluefish are credited with attacking a school of menhaden with such ferocity as to leave a wake of blood and mangled fish for miles, and destroying the school utterly. Baird[2] estimated the number of bluefish over 3 pounds in weight in New England waters at one thousand million. Each fish he credits with the destruction of 10 fish, or 2½ pounds, per day. During the four summer months, he calculates, this number of bluefish

[1] Smith, Hugh M., Notes on an Investigation of the Menhaden Fishery in 1894, with Special Reference to the Food Fishes Taken, U. S. Fish Comm. Bul., 1895, p. 285.

[2] Natural History of Important Food Fishes of the South Shore of New England. II. The Bluefish. U. S. Fish Comm., Rept. 1871–2, p. 235.

devour ten thousand million fish, or twenty-five hundred million pounds, per day; and for the four months, twelve hundred million fish, or three hundred thousand million pounds. Goode[1] applies this approximation to the menhaden. He takes the number of menhaden as one quarter of the total destruction considered by Baird, and supposes that the other predaceous fish combined destroy a number equal to that devoured by the bluefish. This justified a division of Baird's estimate by 4 and a multiplication by 2. The coast of New England, further, is taken as one-quarter of the Atlantic coast of the United States. The number, therefore, should be multiplied further by applying the estimate to the winter months also during which the destruction by bluefish and the others continues in southern waters. Goode finally multiplies Baird's estimate by 10, to obtain a figure representing the annual destruction of menhaden on the entire coast. The product is three thousand million million!

These figures are mere estimates. They serve, however, to show that the destruction of 900,000,000 of menhaden by man is insignificant when compared to the probable destruction wrought by the predaceous inhabitants of the ocean.[2]

OTHER FISH USED IN THE PREPARATION OF FERTILIZERS.

WASTE FROM DRESSED FISH.

The discussion of this topic, it should be said in the beginning, will have to do with the possible use of other fish in the preparation of fertilizer, rather than with the actual use, for the amount of fertilizer produced on the Atlantic coast from other fish than the menhaden is almost negligible.

With the exception of the menhaden there are no fish sought on the Atlantic coast besides the food fish. As a source of scrap from fish other than the menhaden, one would have to look, then, to the waste from the food-fish fisheries and to useless fish taken incidentally in these.

According to the statistics of 1908, the latest year for which statistics are available, 703,525,500 pounds of food fish were caught in the Atlantic and Gulf fisheries of the United States. In the dressing of fish the waste represents an average of 25 per cent of the "round" weight of the fish of the above catch; then, 175,881,375 pounds, or 78,518 tons, of fish refuse suitable for the preparation of fertilizer were produced. This amount would be further augmented by the portion of the catch thrown away because of having spoiled in the market or because of lack of market and the large number of useless fish, mostly dogfish, taken incidentally. On the supposition that this material, consisting of the heads and viscera, contains 10

[1] Loc. cit., p. 109.

[2] In this connection see Kendall, Bull. Bureau of Fisheries, 1908, Pt. I, p. 281, and Hathaway, ibid., p. 271.

per cent solid matter (round fish have been shown to contain 19 per cent solid matter[1]), the quantity of refuse would produce 7,852 tons of dried fish scrap.

The utilization of any considerable portion of this waste for the preparation of dried scrap, it will be seen, is economically impossible when it is remembered that the fisheries are scattered the length of the coast, that many fish are shipped to the various markets undressed and are dressed either there or by the consumer, and that the fresh fish marketed dressed frequently are prepared on board the fishing boats and the waste is thrown overboard. At present it is true that practically all of the fish heads and offal available for fertilizer purposes is the comparatively small amount produced at the canneries. The fish-canning industry is carried on on the Maine coast more actively than at any other locality on the Atlantic seaboard, where a number of different sorts of fish, but principally herring, are preserved. To a certain extent the waste from these industries, known as "fish cuttings" and consisting of the heads and viscera, is treated for the recovery of its oil and the preparation of fish pomace or raw scrap.

Concerning the practice at the herring canneries of the Passamaquoddy region of maine, Hall[2] states:

> The "fish cuttings" and refuse fish which accumulate at the canneries are made into pomace and sold for fertilizer. When the herring are cut for sardines the "cuttings," which include the heads and viscera, are first deposited in barrels. They are afterwards removed to the press room and emptied in a heap on the floor, being spread in layers and covered with salt to prevent them from decomposing. The quantity of salt used is about 3 bushels to 5 barrels of cuttings. After remaining in the salt a short time they are put into three-quarter hogshead tubs and thoroughly cooked with steam. * * * The tubs are kept covered while the fish are cooking. After being cooked, the cuttings are dipped with scoop nets from the tubs into the pomace presses. There are usually two of these presses used in each cannery. * * * The pressure is applied with a jackscrew operated by hand. While the fish are being pressed the oil and water which they contain are carried off into an oil tank by means of an open spout. The pomace, when taken from the press, is packed into barrels which are made for that purpose and hold about 275 pounds each. It is sold largely to farmers in the vicinity at an average of about $9 per ton. The oil is skimmed off the water in the tanks and put in barrels for shipment. The price received in 1895 was about 14 cents per gallon. * * *
>
> It requires about 3 hogsheads of fish to yield 1 hogshead of cuttings and 5 hogsheads of cuttings to make 1 ton of pomace. It is generally estimated that the yield of oil to each ton of pomace is from 20 to 23 gallons, but the proportions in which the two products are sold show the average quantity of oil to the ton of pomace to be a little less than 16 gallons.

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[1] Cf. p. 32.

[2] The Herring Industry of the Passamaquoddy Region. U. S. Fish Comm. Rept., 1896; cf. p. 479.

In 1895, according to the figures compiled by this authority, 36,496 hogsheads, or about 36,496,000 pounds, of herring were utilized in the canning industry of the Passamaquoddy region. In the same year 325 gallons of oil, 31 tons of pomace, and 2,704 barrels of waste fish, which were not rendered, were produced.

In 1905, 33 establishments were engaged in canning sardines. Fifty tons of pomace and 1,000 gallons of oil were produced. The former fetched $8 per ton and the latter 15 cents per gallon.[1]

Small amounts of the waste produced at the fish-dressing establishments of the fishing centers of Massachusetts are utilized by the renderers of garbage and other city wastes of those sections. These amounts are irregular and of small consequence. Undoubtedly they could be increased. In the neighborhood of Pensacola, Fla., a plant recently has been established for the utilization of the fish scrap and waste fish available in that region. It is said on good authority that large quantities of mullet, caught on the Florida coast south of Tampa, annually are permitted to go to waste for lack of suitable market. In previous years skates and other useless fish taken in the pound nets at certain places on the New England coast were dried in the sun, without rendering, and subsequently were pulverized for use as fertilizer.

REFUSE FROM NEWFOUNDLAND COD.

The large production of fish waste from the extensive cod industry prosecuted on the Newfoundland shores has been the object of much speculation in the past. An investigation of the industry has shown that about 150,000 tons of refuse is produced there annually. If this be regarded as containing 15 per cent solid matter, it would be equivalent to over 20,000 tons of dry scrap. This amount of fish scrap would be an important addition to the present output from the Atlantic fisheries. It has been shown, however, that the scrap is produced in small amounts over a long line of shore, that it is thrown away as fast as produced, thus requiring to save it a radical change in the present methods of work, and that it is produced at a time when all the available labor is busily engaged in dressing the cod. Its recovery accordingly constitutes a problem which so far has not been solved economically and offers scant hope of solution.

DOGFISH.

Perhaps the most probable extension of the fish-scrap industry through the employment of other fish for that purpose will prove to be the utilization of dogfish. This supposition is based on the consideration of the general hatred for the dogfish entertained by the

[1] Statistics of the Fisheries of the New England States for 1905, U. S. Fish Comm. Rept., 1906.

fishermen and the consensus of opinion there that their destruction is imperative. The insistence that State or Federal initiative be applied toward their destruction combined with a realization of their utility when captured may possibly lead to their large use as a source of fertilizer.

In 1904 the Canadian Government brought about the erection of three plants for the rendering of dogfish, one at Clarks Harbor, one at Canso, Nova Scotia, and the other at Shippigan, on Chaleur Bay, New Brunswick. These were operated on the basis of Government ownership of rendering plant, and cash payments to the fishermen, by the ton, for dogfish delivered at the docks.

With regard to one of these plants the Massachusetts Board of Fish Commissioners has to say:[1]

This establishment * * * was designed to reduce about 10 tons of dogfish or fish offal daily. The machinery used * * * is of the type generally used in the menhaden factories in this country, and with certain modifications in the whale factories of Newfoundland. At the time of beginning operations, Mr. Cox was obliged to make a week's trip among the fishermen to explain the plan and to induce them to bring in the dogfish caught. As soon as shipments began to come from points outside of Canso, e. g., Arichat, Petit de Grat, etc., the Canso fishermen began to save their dogfish. The result was a great surprise to all. It had not been realized how many dogfish had been hooked and thrown overboard again. One of the fishermen had two trawls set with 1,500 hooks on each. He tended the first trawl as soon as the second trawl was set, and nearly every hook had a dogfish. On October 2, in spite of the fact that notice had been sent out the two days previous that, on account of the overwhelming quantities which came in, no dogfish would be received until October 4, we saw eight loads from steamers, small schooners, and dories brought and landed upon the dock. Three dories brought 7 tons, three small schooners brought 17 tons, and one small steamer brought 8 tons, a total of 32 tons. The price paid for the fish delivered on the dock was at that time $6 per ton if livered and $5 if unlivered. These prices include the livers. Even at $4 per ton the dogfish would have been a bonanza for the fishermen. Two men in a dory could easily make $7 to $8 a day per man catching dogfish within 1 mile of their homes.

With regard to the success and present status of these Government-owned rendering plants, the deputy minister of marine and fisheries of the Dominion of Canada, under date of February 21, 1913, has to say:

As the dogfish became a very serious menace to the successful operation of the fishermen, it was decided in 1904 to test the feasibility of combating the nuisance they caused by converting them into fish scrap and oil. To this end three reduction works were established, which were equipped with machinery manufactured by the American Process Co., of New York. It was the hope of the department that it could be shown that the utilization of dogfish in such a way could be made to pay and that private enterprise would after a few years take up the venture. The works have been operated only during the

[1] Report of the Commissioners on Fisheries and Game. Damage Caused to the Fisheries of Massachusetts by Dogfish During the Year 1905.

season that dogfish are on the coast in large numbers, but it has been found impossible to make them pay with the price that has been paid for the raw material, $4 per ton. The works were established at Clarks Harbor, Nova Scotia; Canso, Nova Scotia; and Shippigan, New Brunswick. Owing to the manner in which fishing is carried on in the vicinity of Shippigan it was not found possible to get any large quantities of dogfish there, and the works at that place have consequently been closed. Last year at Canso over 1,000 tons of dogfish were treated, which yielded about 125 tons of scrap and about 13,500 gallons of oil. At Clarks Harbor 360 tons of raw material were handled, which yielded 48 tons of scrap and over 2,600 gallons of oil. The amount of raw material collected at both these works varies from year to year, depending on the plentitude of dogfish. At Canso the average quantity used yearly would be 1,000 tons, and at Clarks Harbor slightly less.

There is no doubt, however, that such works could be made to pay if located at places where fish offal is also available in considerable quantities and the dogfish were procured at a smaller price.

It has been stated by Field[1] that the two dogfishes, the smooth and the horned, are tremendously destructive of lobsters and of such food fish as the mackerel and herring. The Massachusetts State Board of Fish Commissioners have estimated that the annual loss from the destruction by dogfish of food fish and fishing gear in the State of Massachusetts alone amounts to $400,000. A proportionate loss from their depredations probably obtains for the other States bordering the Atlantic, and a proportionate benefit would accrue from their destruction.

The method of reproduction of dogfish is quite different from that of fish of the herring family, in that fertilization of the eggs of the dogfish is internal and the young fish are brought forth in a fully developed condition. Each female produces from 4 to 12 young at a time. The eggs of a single menhaden, if permitted to hatch, would produce many thousand young fish. When the enormous rate of their increase is considered, it is readily seen how the menhaden are able to persist in spite of the destruction of such vast numbers of them by their various enemies. The dogfish, on the other hand, apparently has but few enemies powerful enough to effect his depletion. Undoubtedly their destruction by natural causes is comparatively slight, so that their comparatively low rate of reproduction is sufficient for the maintenance of their numbers. Their low rate of reproduction makes them particularly vulnerable to the attack of their artificial enemies. Their depletion by a concerted and organized attack of the fishermen therefore should be possible. Before such an attack can be expected, however, a ready market must be provided for the dogfish caught by hook or seine.

From the foregoing it appears reasonable to believe that dogfish may prove an abundant source of material for the preparation of

[1] Field, Sea Mussels and Dogfish as Food. Fourth International Fish Congress. Bull. Bureau of Fisheries, vol, 28, Pt. I, 243 (1908); cf. p. 247.

fish scrap and oil. If caught in very great numbers their depletion would seem to be inevitable. Therefore they can not be regarded as a source possessing both permanence and abundance.

CRUSTACEANS.

Horseshoe crabs, it has been reported by Stevenson, have been used in large numbers in certain localities for fertilizer purposes. The heads and shells of shrimps are used, likewise, though their use is both local and unimportant. The shells obtained at lobster and crab canneries have been found to be admirable as "fillers" for finished fertilizers. Besides carrying a certain percentage of nitrogen, they contain a large amount of lime of high agricultural value. At one fertilizer mixing plant on Chesapeake Bay over 250 tons of ground crab shells are used annually.

THE ALLEGED DESTRUCTION OF FOOD FISH IN THE MENHADEN INDUSTRY.

It has been believed by many that not only menhaden have been utilized by the operators for the manufacture of fish scrap, but that any fish available or that could be caught in the seines were so employed, and that in this way great numbers of food fish were destroyed annually. It was asserted that so great was this destruction that the decrease in the supply of food fish along the shores was quite appreciable. In contradiction it was maintained by the fishermen that the number of food fish taken with the menhaden was insufficient to supply the crew with fresh fish and therefore the charges were quite groundless.

In 1894 the Bureau of Fisheries investigated the question of the alleged destruction of food fish by the menhaden fishermen. The results obtained were unqualifiedly corroborative of the claims of the menhaden fishermen. In spite of this investigation and its positive results, the belief is still maintained among certain people that food fish are destroyed in the menhaden fishery. For that reason this brief discussion of the Bureau of Fisheries' investigation is included in this report.

An agent of the bureau mentioned was placed on each of two vessels, one a "double-gang" steamer, equipped with two purse seines and crew requisite for their manipulation, and the other a "single-gang" steamer. The investigation covered the entire fishing season of those steamers, during which time they took about 28,000,000 fish, or one-twentieth of the entire catch of the season.

The fishing operations covered the entire coast from Maine to North Carolina, inclusive of the bays and sounds. The seines were hauled a total number of 1,078 times, 132 of which failed to catch

any fish. The number and haul of fish other than menhaden taken in these hauls are set forth in detail in the subjoined table:

TABLE IV.—*Number and kind of fish taken by two menhaden fishing steamers.*

Kind of fish.	Number.
Alewives or herring (Clupea pseudoharengus, C. aestivalis)	86,898
Amber fish (Seriola Dumerili lalandi)	1
Anchovy (Stolephorus mitchilli)	2
Bluefish (Pomatomus saltatrix)	2,274
Bonito (Sarda sarda)	35
Butterfish (Stromateus triacanthus)	811
Catfish (Ameiurus albidus)	2
Cero (Scomberomorus regalis)	3
Cod (Gadus morrhua)	1
Croaker (Micropogon undulatus)	134
Cunner (Ctenolabrus adspersus)	4
Cutlas fish or hairtail (Trichiurus lepturus)	2
Drums (Pogonias cromis, Sciaena ocellata)	11
Filefish or foolfish (Alutera schoepffi)	9
Flounders (Paralichthys dentatus, Pleuronectes maculatus, Achirus fasciatus, Limanda ferruginea)	369
Gar (Tylosurus, species)	6
Goosefish (Lophius piscatorius)	11
Haddock (Melanogrammus aeglifinus)	23
Hake (Phycis chuss)	40
Hickory shad (Clupea mediocris)	9
Kingfish (Menticirrhus saxatilis)	1
Lamprey (Petromyzon marinus)	11
Lumpfish (Cyclopterus lumpus)	8
Mackerel (Scomber scombrus)	631
Pipefish (Siphostoma fuscum)	7
Pollock (Pollachius virens)	1
Pompano (Trachinotus carolinus)	8
Rudder fish (Seriola zonata)	1
Sculpins (Cottus, species)	19
Scup (Stenotomus chrysops)	73
Sea bass (Centropristis striatus)	39
Sea herring (Clupea harengus)	5
Sea horse (Hippocampus hudsonius)	4
Sea raven (Hemitripterus americanus)	1
Sea robins (Prionotus carolinus, chiefly)	43
Shad (Clupea Sapidissima)	1,816
Sharks (Carcharinus obscurus, Squalus acanthias, Sphyrna zygaena, Carcharias americanus, Mustelus canis, Alopias vulpes, Squatina squatina)	388
Skates and rays (Raia erinacea, R. eglanteria R. laevis, Dasyatis centrurus, Rhinoptera quadriloba)	372
Spanish mackerel (Scomberomorus maculatus)	150
Spot (Leiostomus xanthurus)	20
Squeteague or weakfish (Cynoscion regalis, C. maculatus)	498
Striped bass (Roccus lineatus)	1
Swellfish, swelltoads (Chilomycterus geometricus, Tetrodon turgidus)	6
Tautog (Tautoga onitis)	17
Whiting or silver hake (Merlucius bilinearis)	30
Total	94,795

In addition to those enumerated, a number of large schools of alewives were captured but were released after they had been identified. The alewife, or herring, is useful for the same purpose for which the menhaden is sought, and, besides, is regarded as a food fish. It might be argued that these, released after capture, should have been counted in the returns, as the investigation had to do with the number of fish captured, as well as retained, especially as no evidence was adduced to show that it was the invariable custom of the fishermen to release other fish than the menhaden, suitable for fish scrap and oil purposes, when caught in such large numbers.

TABLE V.—*Showing disposition made of catch.*

Species.	For oil and guano.	Eaten.	Salted by crew.	Sold for bait.	Thrown overboard, etc.
Menhaden	27,732,355		25,000	199,900	2,500
Alewives	71,888	24		10,000	5,000
Amberfish		1			
Anchovy		1			
Bluefish	410	1,292	572		
Bonito	2	16	17		
Butterfish	356	393	50		12
Catfish	2				
Cero		3			
Cod	1				
Croaker	44	86			4
Cunner	2	2			
Cutlas fish	2				
Drum	8	3			
Eel	5				6
Filefish	9				
Flounders	246	93	20		10
Gar	5	1			
Goosefish	8				3
Haddock	15	8			
Hake	28	12			
Kingfish		1			
Lumpfish	8				
Mackerel		631			
Pipefish	7				
Pollock		1			
Pompano	6	2			
Rudder fish	1				
Sculpins	19				
Scup	36	37			
Sea bass		41			
Sea horse					4
Sea raven					1
Sea robin	43				
Shad	266	161	712		[1] 675
Sharks	388				13
Skates and rays	368				4
Spanish mackerel		150			
Spot	20				
Squeteague	31	231	236		
Striped bass		1			
Swellfish	6				
Tautog		17			
Whiting	22	8			

[1] Released alive.

TECHNOLOGY.

FISHING.

The time of fishing for menhaden is determined, of course, by the habits of the fish. Since they appear in northern waters in April and disappear in November, the fishing season then is delimited by those months. As one goes farther south, the season is lengthened; in the Carolinas the boats are not put out of commission until the latter part of December, though fishing does not begin much earlier there than in the northern region. In the southern region the spring and fall fishing furnishes most of the raw material, there being a dull season in midsummer when catches are rare and unimportant. In Florida waters the fish are present throughout the winter.

The range covered by the fishing boats is determined by the habits of the fish, the situation of the factory to a slight extent, and by the

power and speed of the boats themselves. As the menhaden rarely are found north of Cape Cod, that point may be said to be the northernmost limit of the fishing grounds, though often in former years fish have been found farther north than that. At times big catches have been made in Cape Cod Bay and Boston Harbor. The Chesapeake boats, perhaps, cover the wider range, as they habitually fish from Nantucket to Hatteras. This is determined in part by their more central location and in part by the Virginia fishing laws which prohibit boats owned by nonresidents of the State from fishing in the waters controlled by the State of Virginia. As most of the fish are caught within the 3 mile from shore limit, this law rather discourages the boats of the northern fisherman from coming that far south. Since similar laws are not enforced by the other coastal States, the Virginia fishermen enjoy a range not permitted to the boats from other States. At least, the law reserves Chesapeake Bay for the Virginia fisherman.

The boats used in the fishing industry are by no means uniform in construction, though the modern boats built especially for fishing are constructed after a certain general model. (Pl. I, fig. 1.) Without entering into a detailed description of their lines, it may be said that in general they are constructed high at the bow and low amidships. The former adds to their seaworthiness and gives the additional advantage that from the pilot house situated thereon a wider range of vision is afforded. The latter adds to the facility with which the fish may be transferred from the seines to the hold of the boat. The pilot house and quarters are situated in the bow of the boat, while the engine room, boilers, and bunkers are placed toward the stern, the middle portion of the boat being constructed as the receptacle for the fish. This part is provided with large hatches to facilitate loading and unloading. The arrangement is somewhat the same in the small auxiliary schooners, the galley and quarters being situated forward and the engine room aft, the hold for receiving the fish occupying again the middle of the vessel. The larger steamers have a capacity of 750,000 fish and carry a complement of 50 men. (Pl. I, fig. 2.) The auxiliary sailboats have a capacity of about 250,000 fish.

Each boat carries two purse boats. These are towed, being tied together and fastened in closely, so that their bows touch the stern of the fishing steamer or schooner. The purse boats, so named because they are used in spreading and otherwise manipulating the purse seines, were formerly of the whaleboat type, somewhat modified. They are constructed to possess the qualities of steadiness in the water, as considerable active moving about within them is occasioned by manipulating the seines, and of being easily towed and rowed. Formerly, they were of a lap-streak construction, but now

one finds a smooth-bottom boat, with battened seams, in general use. The more flaring sides of the whaleboat have given way to a straighter and more nearly perpendicular shape. The boat might be described as long, deep, and narrow. These changes are said to give greater speed and greater durability on account of the closer seams; and the smooth sides and bottom prevent the entanglement of the twine of the seines. They are 30 to 35 feet in length and are provided with a platform, running their length, with elevations fore and aft.

The purse seine is in general use among the menhaden fishermen. Its adoption marked an important stage in the development of the industry due to its great superiority over the older forms. The seine is about 1,500 feet long by 180 feet wide. When extended in the water it is supported by a row of corks fastened along its top. The distinctive feature of this form of seine is the arrangement provided for drawing it together, pursewise, at its bottom. At frequent intervals along its lower edge are suspended metal rings, about 3 inches in diameter (which also serve as weights to keep the seine fully stretched), through which passes a rope. The ends of this purse line are held in the purse boats. When the fish have been surrounded and the two ends of the seine brought together by hauling on the purse lines the bottom of the seine is drawn together. This prevents the fish from escaping by diving beneath the bottom of the net. As the seine is carried partly in one boat and partly in the other, to spread it it is necessary only to row the two boats in opposite directions, paying out the seines as the boats separate. (Pl. II, fig. 1.) In fishing this is done in such a way as to intercept and surround a school of fish. When the two boats have met on the side of the school opposite to that from which they started the purse line is hauled in to draw the seine together at the bottom, and the fish are secured. The seine is then hauled in to force the fish into a smaller compass. Following that the steamer is brought alongside and the fish are dipped from the seine by means of a large dip net, operated by an arrangement of block and tackle, and emptied into the hold. (Pl. II, fig. 2.)

UNLOADING.

Unloading at the docks was formerly effected by means of tubs filled by hand and hoisted to the docks by means of block and tackle. This has been supplanted at practically every factory by one or two elevators. These are bucket elevators and are an adaptation to the handling of fish of the apparatus employed in unloading wheat. The elevator is fed partly automatically through the fish sliding toward it of their own weight and partly through the aid of three or four members of the crew armed with shovels.

The elevator deposits the fish in an automatic measuring device, which is of different form at different factories. It may have the form of two bins provided with a device for diverting the stream of fish into the other when the one has attained a certain weight, the bottom of the loaded bin being opened at the same time. A form is frequently found which has the shape of a cylinder divided into segments and mounted so as to revolve horizontally on an axis. When one segment of the cylinder has received a definite weight of fish the cylinder is revolved through an angle, a new section is brought into position to be filled, and the one filled is emptied.

Measuring the catch is an important operation, as upon it is based the bonus to be paid the fishermen. In the North the captain of the steamer and perhaps his first officer are paid on the bonus basis, while in certain parts of the South the entire crew are so compensated. While fish are rated in thousands, less frequently in barrels, actually they are not counted at all but are measured in bulk. The space occupied by a single menhaden arbitrarily is taken as 22 cubic inches; however, since they vary so widely in size the volume of an individual may be far from that. A thousand, accordingly, are considered to occupy 22,000 cubic inches. This bulk of fish, whether occupied by 500 or 2,000, is rated as a thousand, weighs 666 pounds, and is equal to $3\frac{1}{3}$ barrels.

From the measuring apparatus the fish are deposited in storage bins from which they are carried as needed to the cookers. The transfer may be made by cars or by automatic conveyors, depending on the equipment of the plant.

The operations so far mentioned are typical and are in vogue, with slight modifications, in practically every plant on the Atlantic coast. The subsequent treatment of the fish, however, varies widely with respect to apparatus, though it follows in general one of two methods which may be styled the old or discontinuous method and the new or continuous process. Due to the gradual displacement of the old apparatus by the new, all combinations of the two processes are found.

COOKING (OLD METHOD).

The old method of cooking in open vats is still in vogue in such a number of factories as to justify its description here. The vats employed are usually situated on the second floor of the factory so that the oil and water subsequently to be pressed from the cooked fish can follow its prescribed course through the plant without the assistance of pumps. They are constructed of wood or cement, with a false bottom, beneath which are placed steam pipes. The individual vats may have a capacity of about 20,000 fish, and the entire set of vats, 300,000 fish. They are arranged generally in two adjacent longitudinal rows. Above them runs the track conveying the tramcars or the

FIG. 1.—FISHING STEAMER.

FIG. 2.—CARGO AND CREW OF FISHING STEAMER.

FIG. 1.—ILLUSTRATING THE OPERATION OF A PURSE SEINE.

FIG. 2.—BAILING THE FISH FROM THE SEINE INTO THE STEAMER.

automatic conveyor which supplies the fish to be cooked, while along either side of the double row are placed other tracks running to the presses.

Fish are dumped into the vats in quantities depending on the capacity of the vats, usually 50 to 100 barrels, some water is added, and the steam is turned on. They are cooked about 20 minutes, or a sufficient length of time to cause them to break up easily, but not long enough to disintegrate them entirely. The object of the cooking is to break the oil cells or to bring about that condition which admits of a more ready expressing of the oil. If the cooking is too prolonged this is accomplished also, but the flesh is so thoroughly disintegrated that it becomes a mush from which it is difficult to separate the oil. The oil, water, and fine particles of flesh would squeeze out of the presses together.

PRESSING (OLD METHOD).

The cooked fish are thrown from the vats into the curbs of the presses by means of a modified shovel which retains the solid matter and permits the water to run back into the vats. The curbs are mounted on trucks and are brought alongside the vats by means of the track, spoken of above, which parallels the rows of vats. The curbs are generally tubs, whose cross section is a circle, constructed of metal slats with an outward slant. The spaces between the slats are of a suitable width to permit the water and oil to escape when the pressure is applied, but to retain the solid matter. The spaces are of the same width from top to bottom, since the outward slant of the slats is compensated for by the increased width of the slats. The bottom is hinged, and, while securely fastened, its lock is readily manipulated and the bottom easily released. An iron shield is generally placed around the curb to protect the workmen from the jets of water and oil which escape from the curb when pressure is applied.

The curb, when it has received its charge of fish, is rolled back beneath the press and the power is applied. In certain of the smaller factories in the Beaufort region screw presses, manipulated by hand, are still in use. Most of the other plants using the older, discontinuous method of expressing the fish, however, are equipped with hydraulic presses.

The escaping water and oil is caught by the properly slanting floor as is also that escaping from the curb during charging and conveyed to the oil room for settling and further treatment. When the maximum pressure has been applied and no more liquid is being forced out the pressure is released, and the curb is rolled over an opening in the floor for emptying. The bottom is then released and swings downward, and the mass of fish scrap falls in a solid cake to the floor below. The slanting sides of the curb are designed to

facilitate the discharge of this cake; the curb being larger at the bottom than at the top, the cake falls out readily. At this stage, the scrap contains about 50 per cent water, by weight, and about 6 or 9 per cent of oil. In its warm and moist condition it makes an ideal breeding place for various flies and for the growth of decay-producing bacteria. Unless it is to be immediately dried, it is treated with crude sulphuric acid ("about a dipper full (3 quarts) to a cart-load") in small but sufficient amount to discourage the development of insect and other life therein. The acid, besides acting as a preservative, brings about a disintegration of the flesh and bones of the scrap. It is claimed to "dissolve" the bone and to "fix the ammonia." It does render a larger proportion of the phosphoric acid of the bones "available" and may possibly convert some of the nitrogen of the complex organic bodies in the flesh into ammonia, to form ammonium sulphate. What is meant by this fixation probably is that the decay of the fish, leading to the loss of nitrogen or possibly to the actual liberation of ammonia, is prevented. This so-called "acidulated" or crude scrap may be sold as such, or, as opportunity presents, finally may be dried.

DRYING (OLD METHOD).

The old platform dryer has been supplanted in almost every factory on the Atlantic coast by the modern and more rapid hot-air dryer. As must be inferred from the name, the platform method consists merely in spreading the scrap on a platform, where it is exposed to the air and sun. The platform in some cases is built of boards raised a few inches from the ground and in some cases is made of concrete. The scrap is frequently stirred either by hand rakes or hoes or by scrapers drawn by horses. At night, or when rain is threatened, the scrap is raked into heaps and covered with canvas. Under favorable conditions, three days drying is required. The product obtained by this method of treatment is a much lighter brown in color than that dried by hot air. Its odor is also less marked. It is said that considerable ammonia is lost by thus exposing the scrap so thoroughly and for such a long time to the air. Whether fish scrap loses nitrogen on exposure to air when in a nearly dry condition and when no recognizable decay is taking place is a mooted question. Experiments bearing on this point are under contemplation in this laboratory.

COOKING (NEW METHOD).

The new method of cooking fish has largely supplemented the old because of its speed and efficiency and the saving in labor which it effects. The apparatus employed is essentially a long, narrow, iron cylinder (Pl. III), of varying length, but frequently about 40 feet,

and about 2 feet in diameter, through which the fish are passed by means of a screw conveyor, being subjected the while to the cooking action of steam. These usually are constructed for a capacity of 100,000 fish per hour and may be purchased at a cost of about $1,200.

There are several forms of this apparatus, differing from each other principally in the manner in which the steam is admitted to the cylinder. Thus, it may be admitted through perforations in the hollow shaft of the screw conveyer; the blades of the conveyer may be displaced by sections of iron pipe, arranged screwwise around the axis, through perforations in which the steam may enter the chamber; or it may be admitted through numerous pipes projecting through the casing along its bottom. The second and third methods mentioned are regarded by the operators as more efficient, as they admit the steam within the mass of fish, instead of above it, and thus effect more thorough and uniform cooking.

The fish are conveyed automatically from the storage bins and are dumped continuously into the hopperlike mouth of the cooker. This, in certain forms, is provided with a special device for regulating and assisting the feeding. The cooked fish, together with the water and oil cooked from them and the water resulting from the condensed steam, are passed from the end of the cooker into the buckets of a conveyer and are transported to the presses.

PRESSING (NEW METHOD).

The modern power press employed in the fish-scrap industry has the shape of a truncated cone placed in a horizontal position. It is essentially a curb constructed of iron, with slatted sides. Through its center passes a horizontal shaft on which is built up a screw, tapered to fit closely inside the cone-shaped curb. The rotation of the screw carries the fish forward into the smaller end of the curb, and as the material can not rotate with the screw or slip on the curb it is subjected to pressure. By adjusting the size of the opening in the smaller end, through which the expressed material is ejected, the pressure on the mass may be increased or decreased. The pressure is gradual, increasing from the larger end toward the smaller. The water and oil are squeezed out between the slats and are caught by the metal shield surrounding the press and are conducted thence into pipes leading to the oil room.

The mouth of the press is hopper shaped. The fish are fed into this by a mechanical conveyer. In some forms of the press a chopper is placed in the mouth to reduce the size of the pieces of fish entering. From the smaller end of the press the fish scrap usually is allowed to fall into the buckets of a conveyer.

One hundred pounds of the mass coming from the cookers contains 22 pounds of fish and 78 pounds of water. In the press 56 pounds is

removed. This leaves a mass of 44 pounds, 22 pounds of which is fish and 22 pounds (50 per cent) water.

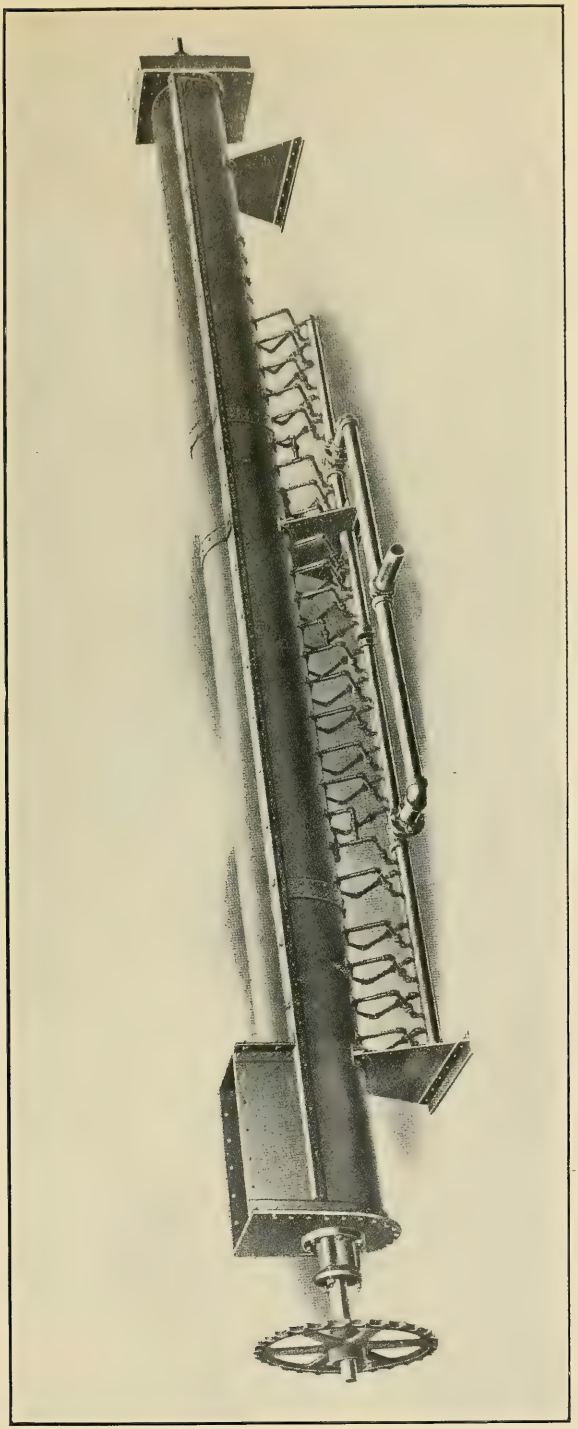
The 18-foot power press is obtainable at a cost of $5,000, set up complete. (Pl. IV.) This has a capacity of 80,000 to 100,000 fish per hour. A smaller press, 12 feet in length and with a capacity of 40,000 fish per hour, may be purchased, complete and set up, for $3,500.

The advantages of this system of ridding the fish of their water and oil are obvious. Its speed and the fact that it is continuous and automatic, requiring no labor, have enabled it to displace the discontinuous hydraulic press in a number of old factories and have brought about its adoption in practically all of those recently constructed.

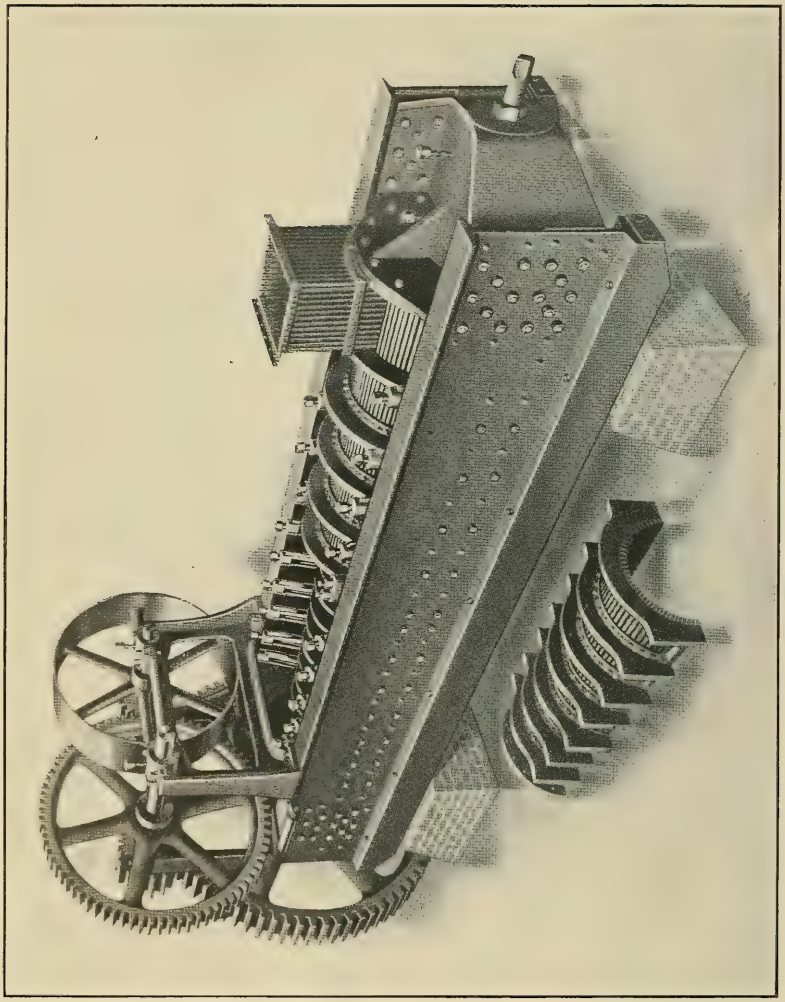
DRYING (NEW METHOD).

The hot-air drier is now in use in all but four of the fish-scrap factories on the Atlantic coast. In at least two of the factories it has not been adopted because of the hostility of the residents of the neighborhood occasioned by the odor arising from the factories, increased during the actual operation of the drier, and exhibited by frequent suits at law.

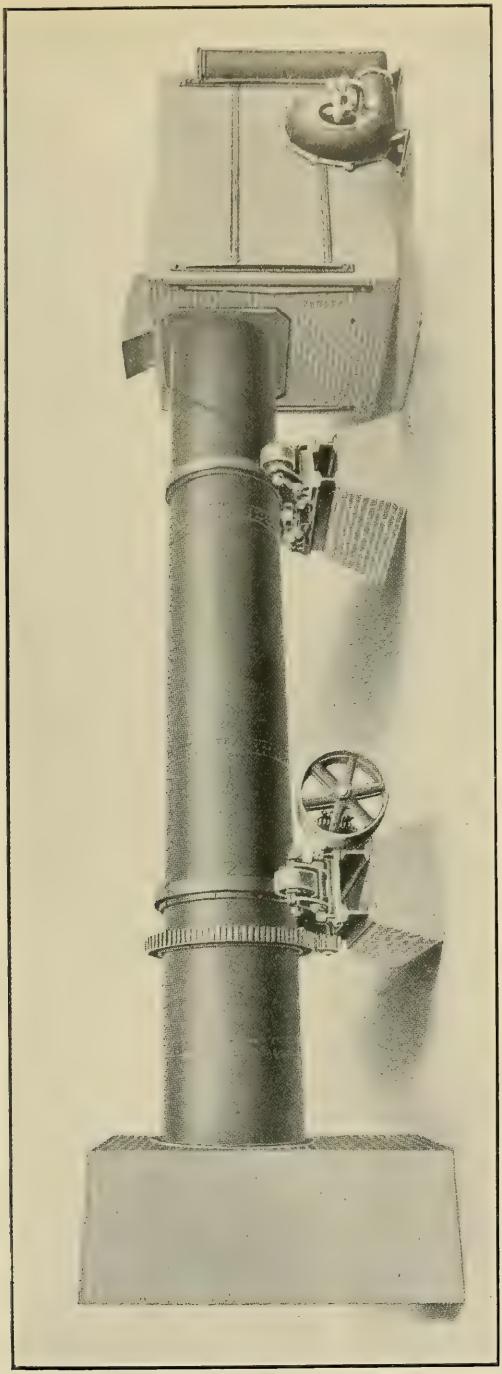
The modern drier (Pl. V.) is an insulated iron cylinder, about 6 feet in diameter and 30 or 40 feet in length. It is provided on the inside with a series of iron flanges or shelves, about 8 inches wide and running the length of the cylinder. These are designed to lift the scrap and spill it again through the stream of hot air. The cylinder is mounted slightly out of the horizontal and is supported by a device consisting of two jointless steel tires or rings encircling the cylinder toward each end and resting on steel rollers or wheels. These rollers are rotated by suitable gearing, driven by an electric motor, and they in turn rotate the cylinder. Its higher end, which is the front end, enters a brick chamber, the bottom part of which constitutes a fire box. Suitable openings are provided for stoking, etc., and an electric fan is also provided to produce a forced draft. The wet fish scrap is charged at this end, being allowed to drop directly into the swift stream of hot gases entering the cylinder from the furnace. The forced draft serves also to blow the scrap through the kiln as it is repeatedly lifted and dropped in the rotation of the kiln. The finer particles, which are more quickly dried, are blown more rapidly out of the zone of fiercer heat. The movement of the scrap through the kiln is induced, then, both by the draft and by the slope of the cylinder. The lower end likewise enters a brick chamber, practically cubical in shape, designed to fill the threefold purpose of catching the scrap as it falls from the cylinder, of acting as a sort of dust settling chamber, and of serving as a rather inefficient chimney. From this chamber the scrap is conveyed,



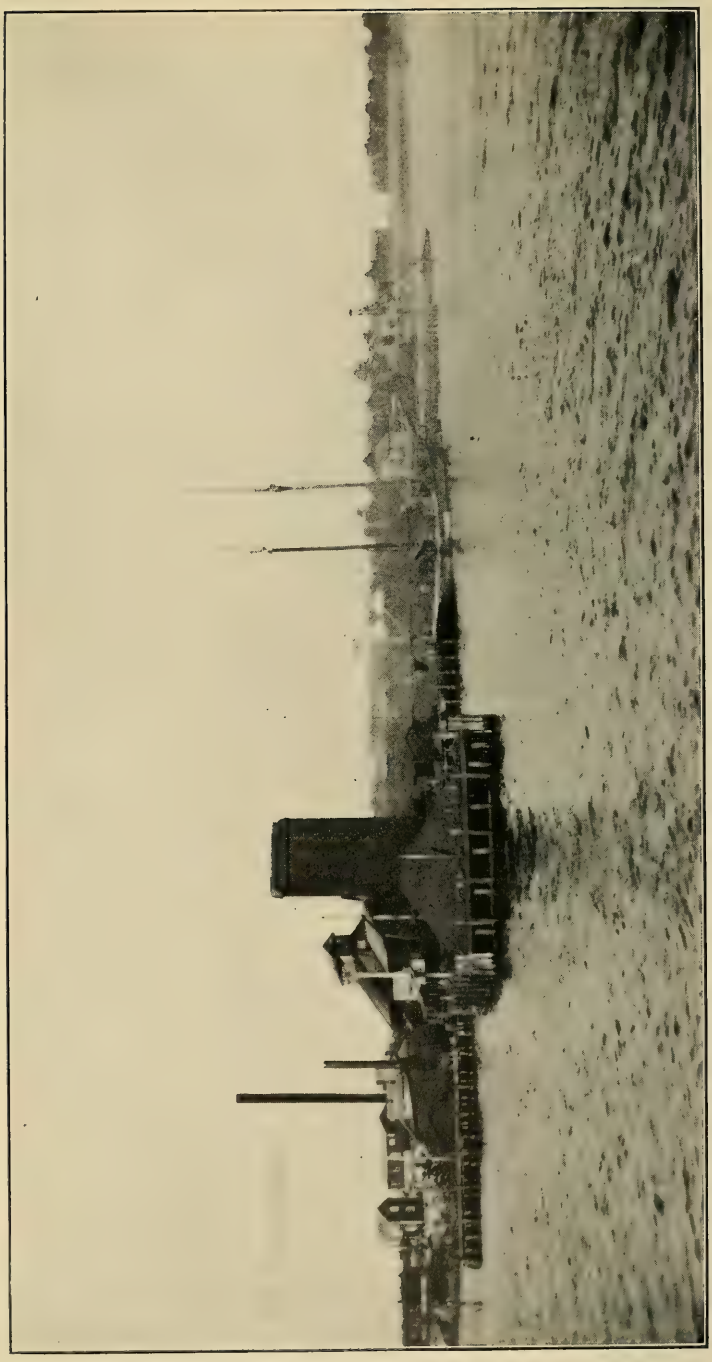
AUTOMATIC STEAM COOKER.



AUTOMATIC POWER PRESS.



HOT-AIR DRYER.



FISH FERTILIZER AND OIL FACTORY NEAR REEDVILLE, VA.

again by bucket conveyer, to the warehouse where it is stored, ground, and bagged. The transit through the drier consumes from 3 to 20 minutes, depending on the force of the blower, the rate of rotation of the kiln, and the degree of fineness of the lumps of scrap on entering the kiln. The moisture content is reduced to about 7 per cent. As some of the kilns are being operated, about 5 tons of coal per day is consumed. According to the various estimates of the operators, a million fish produce 75 to 85 tons of dry scrap; 12,000 to 15,000 fish are required to make 1 ton of scrap. The drier, complete and set up, may be purchased for $3,000, inclusive of blower, bricks, etc.

The hot-air drier for fish scrap is a useful piece of apparatus, and its introduction marks an epoch in the fish-scrap industry. It has rendered it almost altogether unnecessary to acidulate scrap, since the drier practically always is able to handle the output of the cookers and presses. In the plant equipped with a full set of the improved machinery the fish are not moved by manual labor from the time they are fed to the elevator in unloading until the dry scrap is being bagged. The whole operation requires less than an hour.

Theoretically, the hot-air drier is inefficient. Theory requires that in drying the drying agent shall be passed over the material being dried in a direction opposite to that in which that material is moving. Thus, in drying by a stream of hot air, the hottest and driest air is brought into contact with the driest material, and as it becomes more heavily charged with water vapor, passes progressively over wetter and wetter material. In this way the maximum moisture absorbing power of the air is made of use. In the drier in use in the fish-scrap industry, the opposite arrangement obtains, the hottest and driest air is brought into contact with the wettest and coldest fish, and the wettest and coldest air into contact with the driest and warmest fish. The objection raised to the former procedure is that the dried scrap is inflammable and a careful regulation of the temperature would be required to prevent the scrap from catching fire. There is little danger of this with the present scheme. However, it would be a simple enough matter to lower the temperature of the drying gases far below the ignition temperature of the dried scrap by introducing a sufficiently large volume of cold air into the gases from the furnace; or the fire could be largely reduced in size. Certainly the same amount of drying could be effected with a smaller consumption of coal, or with the same consumption of coal more efficient drying and, possibly, more rapid drying could be made possible by the use of a larger volume of air, and the process could be made as automatic as the present process.

A more serious objection to the present practice in drying scrap is the undoubted destruction of a part of the scrap in the drying.

As was stated, the wet scrap is dropped directly into the white-hot gases from the furnace. The scrap as it enters is in the form of lumps varying in size from the smallest particles to masses several inches in diameter. With a heat intense enough to dry the larger lumps in a maximum of 20 minutes, it is evident that the finest particles must be utterly consumed. The greater speed with which they travel must save much of that in the form of the less fine particles. This is an a priori conclusion, but is practically indisputable. Whether the loss is serious or not can not be said until more experimental evidence is adduced.

When there is much combustion of the fish the fact is further attested by the odor of the smoke which emerges from the "stack" of the drier. This is then a heavy smoke, largely mixed with steam and distillation products and smelling most offensively of scorched flesh. It carries also numerous fine particles of scrap, which in the course of a year's run must represent a considerable loss.

In certain neighborhoods where the majority of the residents are not in sympathy with the industry the hot-air driers are not used at all, or if used, are operated only at night or when the wind is offshore. A tall stack, while an expensive adjunct to a plant, to a considerable extent would alleviate this objection to the use of the drier.

GRINDING AND BAGGING.

After drying it remains only to bag and ship the fish scrap. Some scrap is shipped in bulk, being transferred by conveyer directly to the hold of the transporting vessel. Much is bagged without further treatment; some is ground to a meal before bagging. For the ground scrap a slightly higher price is obtained, representing little more than the cost of grinding. In certain mills the scrap is mixed ("manipulated") with phosphate and potash carriers to produce a so-called complete fertilizer, and is thus marketed under brand names. Other companies are planning an extension of their present operations in that direction. In certain other instances the scrap is shipped to manipulating plants owned and operated by the fish-scrap company. In all other cases, with the exception of the small amounts used locally and as chicken feed, the scrap is shipped directly to the mixers of finished fertilizers.

THE FACTORY.

In locating a factory for the manufacture of fish scrap an attempt is made to obtain a combination of deep water, protected harbor, and nearness to fishing grounds. (Pl. VI.) An effort is made further to find a location that is sufficiently isolated to obviate the danger of litigation on the grounds of being a nuisance because of

odors at times created at the plant. Since fish almost invariably are unloaded from vessels of considerable tonnage and draft, proximity to a water course of sufficient depth is essential to permit the fishing boats to approach their docks. In the case of most of the plants, docks of only moderate length have been required. In one instance the entire factory has been built over the water.

The elevators and other hoisting and unloading devices are situated on the ends of the docks. The storage bins likewise may be built on the docks, though more generally they are to be found closer to the factory. If the former, they are so situated with respect to the elevator that they are supplied directly from the measuring apparatus forming a part of the elevator; if the latter, they are fed by cable cars or automatic conveyers. The bins are situated at such an elevation that the fish after leaving them again do not have to be raised to any considerable height. In accordance with this arrangement, the cookers and presses are placed on the second floor of the factory, the cooker at a greater elevation than the press, and the drier on the ground floor.

The equipment of the average factory consists of one dock, elevator, bin, cooker, press, and drier, with a capacity for the factory of about 100,000 fish per hour. The largest factory on the coast has two cookers, each of 500 barrels per hour capacity, and six presses. The usual rate of operation of this plant is 600 to 900 barrels fish per hour. It has produced oil at the rate of 75 barrels per hour.

Besides the equipment mentioned there is required also a steam and power plant to supply steam for the cookers and oil boilers and to furnish power for driving the machinery. For the average plant, of one working unit, a boiler capacity of about 300 horsepower is adequate. Certain plants generate their own electric power, and at least one has installed separate electric motors for driving the various pieces of apparatus with moving parts.

Capacious storehouses are provided to hold the dried scrap. These usually are built as a separate part of the plant to reduce fire risks, and often are capable of holding the season's output. Bagging is usually done by hand at times when the rest of the plant is lying idle, and is carried on in this building. The output of a plant is determined, not by its capacity but largely by the number and success of the boats fishing for that plant. The average number of steamers operated by a factory is 3. One company operates 27 steamers, 11 of which carry their catches to one factory, while certain manufacturers depend for their supply entirely on the fish sold to them by fishermen working independently. The price of raw fish varies from season to season; during the summer of 1911 $2.25 was paid for 1,000, while during 1912 raw fish brought $1.50 to $2 per 1,000. Since so much

depends on the fortunes of the fishermen, the supply of fish is uncertain and irregular. No plant runs constantly at capacity. Some may stand idle for months in the midst of the fishing season. The fish are worked up as received. This is especially necessary in warm weather, when the fish often bruised and softened by the crushing produced from their own weight, are sure to spoil rapidly. Accordingly, the factories are operated intermittently. A much higher daily capacity is maintained therefore than would be necessary in handling a raw material of a more permanent character, or one supplied with greater regularity.

THE FLOATING FACTORY.

The perfection of the automatic apparatus for handling fish scrap with dispatch has been followed by another attempt to manufacture scrap in a vessel capable of following the menhaden during the season. In July, 1911, the *Mills* was put into commission. This steamer is a converted steel dredge of 5,000 tons, which has been equipped with two elevators, one on each side, with a capacity of 1,500 barrels of fish per hour. These deposit the fish into receiving bins of 5,000 barrels capacity. A continuous and automatic cooker is provided and a rotary press. Storage room, with adequate fire protection, is reserved for the dried and bagged scrap, and likewise storage tanks capable of holding as much as 3,000 barrels of oil. A wireless outfit is likewise provided.[1]

COMPOSITION OF FISH AND FISH SCRAP.

OLD ANALYSES.

Since fish scrap is sold on the basis of its nitrogen content, a great many analyses of it have been made, both by the manufacturer of the finished goods and the inspectors of fertilizers. Many of these have found their way into the literature. In addition a number of analyses of the entire fresh fish are to be found in the literature. Certain of these are quoted below.

In the following table is given the analysis of fresh menhaden by Cook:[2]

TABLE VI.—*Analysis of fish.*

FRESH.

Constituent.	Proportion.
	Per cent.
Water	77.150
Oil	3.914
Dried fish	18.936

[1] Dismantled at close of season of 1912.

[2] Geol. of N. J., 1868, p. 497.

TABLE VI.—*Analysis of fish*—Continued.

DRIED.

Constituent.	Proportion.
	Per cent.
Lime	8.67
Phosphoric acid	7.78
Silicic acid	1.33
Potash	1.54
Soda	1.02
Magnesia	.67
Chlorine	.69
Organic matter and loss	78.30
	100.00

Browne[1] reports the results of an examination of the composition of sprats, "a well-known fish." A specimen was bruised in a mortar and dried at 212° F. One hundred parts of this contained: Water, 63.65; oil, 18.60; solids, 17.75. Of the solids, nitrogen constituted 11.53 per cent, equivalent to 1.94 per cent of the original sample, and ash, 2.21 per cent. The composition of the ash is given in the following table:

TABLE VII.—*Composition of the ash of two samples of sprats, taken in 1847 and 1848.*

Constituent.	1847	1848	Constituent.	1847	1848
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
SiO_2	Trace.	0.30	Potash	17.23	21.89
Phosphoric acid	43.52	40.49	Soda	1.19	.....
Sulphuric acid	Trace.	1.40	Chloride of potassium	.....	2.31
Lime	23.57	27.23	Chloride of sodium	11.19	2.31
Magnesium	3.01	3.42			
Peroxide of iron	.28	.65	Total	100.00	100.00

Of interest in this connection are the results of analysis of the flesh and bones of the whale given in Tables VIII and IX. The analysis is by Stockhardt.[2]

TABLE VIII.—*Analysis of flesh of the whale.*

Constituent.	Raw.	Perfectly dry (including fat).	Without fat and entirely dry.
	Per cent.	*Per cent.*	*Per cent.*
Water	44.50	.....	.....
Fat	22.81	40.70	.....
Flesh	32.10	57.44	96.80
Mineral constituents (ash)	1.04	1.86	3.20
Nitrogen	4.86	8.68	14.60

TABLE IX.—*Analysis of steamed bones of the whale.*

Constituent.	Proportion.
	Per cent.
Water	3.84
Cartilaginous mass (glue)	[3] 34.60
Fat	1.34
Bone phosphate of lime	[4] 51.66
Carbonate of lime	8.56

[1] American Muck Book, 1856, p. 273 et seq.

[2] Chem. Ackersmann, **16**, 52 (1870).

[3] 3.5 per cent nitrogen.

[4] 23.66 per cent phosphoric acid.

The following table contains a number of analyses of fish fertilizers, reported by Atwater:[1]

TABLE X.—*Analysis of commercial fish scrap, quoted from Atwater.*

Kind of fertilizer.	Moisture.	Organic matter.	Ash.	Phosphoric acid.	Nitrogen.	Ammonia equivalent to nitrogen.	Oil.
DRY GROUND FISH.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ground fish, G. W. Miles	18.74	61.82	19.44	7.65	8.06	9.78	6.71
Fish guano, G. W. Miles	21.96	50.99	27.05	8.66	6.07	7.36	.....
Charles Island guano, G. W. Miles	8.63	71.79	19.41	7.74	8.84	10.73	.....
Allyn's fertilizer	.....	.....	16.37	6.17	8.80	10.68	6.35
Do	6.34	71.31	22.35	7.90	7.88	9.56	7.33
Dry ground fish, Quinnipac Fertilizer Co	14.64	.....	22.23	6.67	7.50	9.11	7.68
Do	10.85	68.40	20.75	7.21	7.38	8.97	.....
Do	13.45	63.97	22.58	7.55	7.96	9.66	6.63
Do	8.22	.....	20.41	8.11	8.25	10.00	8.94
Acidulated fish, Quinnipac Fertilizer Co. (dried fish scrap)	36.53	39.89	23.58	[1] 7.09	4.11	4.99	.....
"Dry fish," Green Bros	11.04	64.01	24.95	10.51	8.60	10.44	3.93
"Dried fish"	9.37	.....	19.92	7.10	8.13	9.86	.....
"Dry fish"	11.60	.....	20.17	7.12	7.46	9.05	8.29
"Fish scrap"	7.74	.....	.....	.....	7.10	8.61	.....
"Dry fish"	7.59	.....	.....	.....	7.79	9.46	.....
"Dry fish" (half dry fish scrap)	.....	.....	.....	.....	7.65	9.28	.....
Fish scrap, "half dry"	40.95	43.06	15.99	6.23	5.33	6.47	.....
Fish scrap, "half dry" (crude fish pomace)	25.10	56.17	18.73	7.49	5.49	6.66	11.99
"Fish scrap"	56.83	.....	.....	.....	3.63	4.41	.....

[1] Per cent soluble in water, 1.76; per cent soluble in ammonium citrate, 2.47.

Additional analyses of fish fertilizers, reported by Johnson,[2] are quoted in the subjoined table:

TABLE XI.—*Analysis of commercial fish scrap, quoted from Johnson.*

Kind of fertilizer.	Moisture.	Nitrogen.	Nitrogen in water-free fish.	Oil.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Dry ground fish scrap	10.75	8.52	9.54	.....
Do	.....	8.21	.....	.....
Dry ground fish scrap:				
Old, 1876	16.59	7.35	8.81	.....
New, 1877	23.95	7.30	9.59	.....
Dry ground fish scrap	.....	9.26	.....	.....
Do	.....	8.77	.....	.....
Do	19.57	7.98	9.92	.....
Do	9.03	8.04	8.83	.....
Do	11.38	8.51	9.60	.....
Do	10.74	8.43	9.44	.....
Do	9.76	7.77	8.61	8.94
Do	11.19	8.78	9.88	7.30
Average	13.66	8.24	9.36	8.12
Fish by Adamson's process	4.91	10.78	11.32	2.07
Do	3.67	10.74	11.15	.....
Fish by Goodale's process	11.45	10.24	11.56	4.64

NEW ANALYSES.

A small number of samples of fish scrap were taken for the most part in person by the writer during the fall of 1912. No attempt was made to obtain a complete series from all the plants visited.

[1] Atwater, W. O., Conn. Agr. Expt. Sta. Rept., 1876, p. 63.
[2] Conn. Agr. Expt. Sta. Rept., 1877, 41.

Those obtained may be regarded as typical. The samples were gotten from open heaps of scrap in the storage house, or from bags by means of samplers, or by opening the bags. They were shipped in canvas sample sacks. Before analysis, the entire sample was ground to a powder that would pass a sieve of 16 apertures per linear inch.

METHODS OF ANALYSIS.

Samples of 2 grams were dried to constant weight in an electric oven at a temperature of about 100° C. The loss in weight was recorded as moisture. In this connection it should be said that it is believed that possibly some oil also was lost in this operation. Oil was determined by extracting with ether a 2-gram sample, previously dried to constant weight. Following the extraction, the sample again was dried to constant weight and the loss was taken as oils. For the extraction a Soxhlet apparatus was employed. In the determination of nitrogen the official, modified Gunning method was applied, and in that of phosphoric acid the official gravimetric method was used. The analyses were made by E. G. Parker and J. R. Lindemuth, whose results are recorded in the subjoined table. The eleventh analysis is reported in this table merely for convenience. It is the analysis of pulverized crab shells used as a filler for mixed fertilizers. The particular adaptability of this material for that purpose is brought out by the analysis.

TABLE XII.—*Analysis of fish scrap, by E. G. Parker and J. R. Lindemuth.*

No. of sample.	Location.	Description.	Nitrogen.	Phosphoric acid (P_2O_5).	Moisture.	Oils.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	Kilmarnock, Va.	From Eubanks Tankard Co. Dry scrap (from 6 sacks).	8.93	6.17	6.48	5.91
2	Taft, Va.	From Taft Fish Co. Dry scrap (sample of 525 tons).	8.96	7.75	6.18	6.81
3	Irvington, Va.	From Carter's Creek Fish Guano Co. Dry scrap, dried in hot air and steam driers (from one sack). Fall product.	7.70	5.22	11.68	6.62
4	Cape Charles, Va.	From Atlantic Fish & Oil Co. Dry scrap, ground (from 3 sacks).	9.29	6.12	7.86	5.38
5	do.	From Dennis Fish & Oil Co. Dust from grinders.	8.80	5.21	7.17	7.55
6	Beaufort, N. C.	From Beaufort Fish-scrap & Oil Co. Dry scrap, hydraulic presses. Sample from heap.	8.82	5.95	6.13	8.57
7	Morehead City, N. C.	R. W. Taylor. Dry scrap from open heap.	8.49	5.95	9.12	8.23
8	do.	From Chas. S. Wallace. Scrap, dry, from hydraulic presses.	7.76	9.65	8.15	7.56
9	Lenoxville, N. C.	From C. P. Dey. Ground scrap, sun dried, hydraulic presses. Sample from heap.	7.81	5.85	7.46	7.89
10	do.	From C. P. Dey. Scrap, dry, ground, hydraulic presses. Sample from heap.	8.29	9.00	7.00	5.40
	Average.		9.13	7.25	.....	6.99
11	Crisfield, Md.	From L. E. P. Dennis & Son. Ground crab shells, used as filler.	3.82	4.55	6.95	2.11

USES.

FERTILIZER.

Fish scrap, from the inception of the industry, has met with great success as a fertilizer, until to-day it constitutes one of the main sources of organic nitrogen used in the fertilizer industry. Its nitrogen is in a form from which it is readily rendered available by the bacterial and other action taking place in the soil. The organic matter, which serves as the carrier for the nitrogen, in fish scrap as in other organic nitrogenous substances is a beneficial adjunct not enjoyed by the inorganic nitrogenous substances.

A small amount of fish scrap is used directly as fertilizer without admixture with other fertilizer ingredients or fillers. Its success when used alone has not been unqualified. Its continued application has led to a condition of the soil in which it would no longer respond to that fertilizer. A larger portion is mixed ("manipulated") by the manufacturers of the scrap to form a so-called complete fertilizer and is sold, generally locally, under brand names. During the past year (1912) about 10,000 tons were thus employed. This practice is growing.

By far the larger proportion of the output of the East is sold directly or through the medium of brokers to the larger manufacturers of fertilizers, by whom it is worked up into the various grades of finished goods marketed by them.

CHICKEN FEED.

This use of fish scrap at present is so slight in the East as scarcely to deserve mention. Only a few tons, and these by a small number of chicken growers, are thus utilized; but the success of those so using it, evidenced by their yearly increasing orders, would seem to justify its exploitation by experiment stations and its trial by other poultry raisers.

The following paragraph is quoted, with excisions, from Goode:[1]

> At a meeting of the Maine Board of Agriculture and Farmers' Convention, Mr. Wasson gave an interesting account of the use of "pogy chum" as a food for sheep and poultry, stating that he had used it for five years. * * * Sheep thus fed showed an average increase each of one pound and a quarter of wool, while they were constantly fat and brought heavy lambs. Hens also ate the scrap with avidity. Boyd stated that hens, ducks, and turkeys preferred it to corn, and became large and heavy when fed upon it. It is customary to discontinue the scrap and feed them on corn three or four weeks previous to killing them.

CATTLE FEED.

The use of fish scrap as a feed for cattle has met with such success, seemingly, in those instances where it has been tested that it is surprising that its adoption for this purpose has not become more

[1] Loc. cit. Cf. pp. 140–141.

general. It is reported that in the Shetland Islands dry salt fish constitute the main feed for cattle and sheep, and are even fed to horses.

The most rational method of utilizing fish for manure, and the one which it seems to me must prove by far the most profitable way of economizing our waste fish products, is by feeding them to stock.[1]

The following paragraphs are quoted from a paper by the eminent nutrition expert and food chemist, the late W. O. Atwater, which has been published as a part of the report by Goode:

The earliest accounts which I have met of fish as food for domestic animals is the following extract from the Barnstable (Mass.) Journal of February 7, 1833:

"The cattle at Provincetown feed upon fish with apparently as good relish as upon the best kinds of fodder. It is said that some cows, kept there several years, will, when grain and fish are placed before them at the same time, prefer the latter, eating the whole of the fish before they touch the grain."

In 1853, Mr. J. B. Lawes, of Rothamsted, England, reported several extensive series of experiments "On the Feeding of Pigs," in which were tested the effects of beans, lentil, Indian corn, and barley meals, bran, and dried Newfoundland codfish as foods for fattening. * * * In speaking of the series in which the fish was fed with maize, barley, and bran in different proportions, Mr. Lawes says:

"In the series * * * where we have * * * a comparatively small amount of nonnitrogenous matter consumed, the food consisted in a large proportion of the highly nitrogenous codfish; and in both of these cases, we had not only a very good proportion of increase to food consumed, but the pigs in these pens were very fat and well ripened. * * * This result is in itself interesting, and it may perhaps point to a comparatively greater efficiency in the already animalized protein compounds supplied in the codfish than in those derived, as in the other cases, from the purely vegetable diets."

The value of fish as food for domestic animals has been attested by experienced and intelligent farmers in our own country.

As early as 1864, if not in fact previous to that date, the attention of members of the board of agriculture (of Maine), and farmers generally was called to the value of fish pomace or scrap as a feeding stuff for sheep, swine, and poultry. In a communication to the board[2] Mr. William D. Dana, of Perry, spoke in high tones of its value as a feed for domestic animals, in which he said:

"Fish pomace, or the residuum of herring after the oil is pressed out, is greedily eaten by sheep, swine, and fowl; and probably pogy chum would be eaten as well. Smoked alewives and frost fish also furnish a food palatable to cattle. Sheep thrive well, get fat, and yield heavier fleeces when fed on this pomace than when fed on anything else produced in this section of the State. Careful and observing farmers, who have fed it, assert that it is of equal value with good hay, ton per ton, and that its value for manure is in no degree diminished by passing it through the living mill, and thus reducing it to a much more convenient state for applying. If it could be sufficiently dried, without other substances, to prevent putrefaction, it would form a valuable article of cattle feed in regions from which it is now excluded by the expense of transportation and its own odoriferous nature."

[1] Goode, loc. cit. Cf. p. 248.

[2] Agriculture of Maine, 1864, p. 43.

It is apparent that the scrap spoken of here as used in these feeding experiments is the undried scrap as taken from the presses. No reason suggests itself why the dried scrap should not be as nutritious as the wet as, theoretically, the drying causes no chemical change in the organic substances of the scrap but merely removes water. The advantages of the dry over the wet scrap as a feed are numerous and great.

Feeding experiments were conducted by Farrington at the experimental farm of the Maine College of Agriculture. Two flocks of lambs, of five each, were chosen, and during a period of 16 weeks one flock was fed corn and hay and the other fish scrap and hay. During the first four weeks of the experiment "the corn-fed flock, weighing 340½ pounds, ate 335 pounds of hay and lost 19 pounds in weight. The flock eating fish, weighing 338 pounds, ate 338 pounds hay and lost 1½ pounds." During the 16 weeks of the experiment the sheep were fed about 2 ounces of fish scrap per head per day and the same amount of corn; in that time the corn-fed flock gained 48 pounds, or 15⅛ per cent, and the fish-fed flock 47½ pounds, or 15$\frac{1}{26}$ per cent. As the fish scrap was unground and contained bones, it was not entirely eaten.

On the whole, then, these experiments [and others[1] described in the report by Atwater, but omitted here[2]] bear unanimous and convincing testimony in favor of the easy digestibility and high nutritive value of animal foods in general and of fish guano in particular when fed to sheep and swine. How far they could be made profitable for other herbivorous animals than sheep has not yet been tested. In the nature of the case there is no reason why they should not be as nutritious for neat cattle as for sheep. As Voit has justly observed, all mammals are at one period of their lives, when living upon milk, carnivorous. * * *

In short, we have every reason, from practical experience, from actual experiment, and from what we know of the nature of the case, to believe that the immense amount of animal waste produced in this country from our slaughterhouses, and especially from our fisheries, can be utilized with the greatest ease and profit to supply the most pressing need of a most important part of our agriculture—nitrogenous food for stock.

The ingredients of fish may be made more available for plant food and their value for manure increased by * * * feeding to stock, thus putting it through a process similar to that by which Peruvian guano has been formed. In this way it can be used to enrich the manure made on the farm, and thus made one of the best aids to successful farming.

Concerning the utilization of fish scrap as cattle feed, Henry, in "Feeds and Feeding," says:

Along the coasts of Europe the waste parts of fish as well as entire fishes not used for human food are fed in dried form to animals. Spier, of Scotland,

[1] By Wolff, Wildt, Kellner, and Weiske, described in Die Landwirthschaftlichen Versuchs-Station, J. f. Landwirthschaft and Landwirthschaftliche Jahrbücher, 1876 and 1877.

[2] Note inserted by writer, J. W. T.

reports no bad influence on milk when reasonable quantities of dried fish are fed to dairy cows. Nilson found that 80 parts of herring cake could replace 100 parts of linseed cake in the ration for cows. The better grades of dried fish meal should be used for feeding farm animals.

In a trial by Schrodt and Peters bran and rape cake were gradually replaced by equal quantities of flesh meal until the allowance of the latter reached 2.2 pounds per head daily. It was found that the customary shrinkage in live weight when in full milk flow did not occur, and there was an increase in the total quantity of milk as well as in the total solids and fat. Flesh meal effected a saving of 2 pounds of feed per head daily, and the cows learned to relish it highly.

According to Kuhn, milk and butter of normal quantity were produced on a daily allowance of 2.3 pounds of fat-free fish scrap supplied with a variety of other feed, no deleterious effects resulting.

The universally affirmative results of all the recorded experiments with fish scrap as a cattle feed leaves little room for doubt as to its efficiency. It is, indeed, surprising that its use as a feed has not been more generally introduced. This is doubtless due to the lack of exploitation on the part of the manufacturers, the ones most vitally interested financially.

It will be recalled that in the beginning of the cottonseed-oil industry the expressed cake was a by-product which found use only in the fertilizer industry. Its subsequent exploitation as a cattle feed gave it a much enhanced value. To-day it is produced in immense and constantly increasing quantities, and the portion of it which enters the mixed fertilizer is proportionally less than the amount used as cattle feed. We should not be surprised if in that particular the history of fish scrap will parallel that of cottonseed meal; that the time will soon come when it will be recognized by both manufacturer and farmer that its preparation and use as a cattle feed is more profitable to both than when employed only as a stimulator for growing plants. And fitting, indeed, it would be that even a small part of the millions of pounds of combined nitrogen carried seaward annually by the rivers should be returned, and after a short cycle again should be rendered suitable for man's consumption.

POSSIBILITIES IN THE DEVELOPMENT OF THE FISH-SCRAP INDUSTRY.

A number of elements, all speculative in character, enter into the question of the possible development of the fish-scrap industry. A discussion of this topic should consider the past history of the industry and the present supply of fish, and should have regard for the probable future demand for nitrogen, for the probable increased demand for fish for food, and for the possibly more complete utilization of waste from canneries.

This topic will be considered briefly in the light of the principal influences liable to affect it. The opinions expressed are based on

observations so far made, which in many particulars are necessarily incomplete. A fuller study of the subject doubtless will cause a certain revision of these opinions.

IN THE LIGHT OF THE PAST HISTORY OF THE INDUSTRY.

From the table on page 7, setting forth the statistics of the fish-scrap industry for the years 1873 to 1898, inclusive, it may be seen that the industry has been on its present basis since 1885. The annual catch has varied, the variation being determined as much, perhaps, by the success of the fishermen—"fishermen's luck"—as by the status of the industry, and the annual output in oil and scrap has not varied greatly from 70,000 tons of scrap and 35,000 barrels of oil. There has not been that growth in the recent past which would warrant a belief in a growth in the future.

During the last year there was quite an impetus noted in the industry, due largely to the very successful season of the preceding year, 1911. While there were a number of new plants under construction or beginning operations in 1912, whose establishment was attributable largely to the prosperous season of 1911, there were others which did not share in this prosperity and were either out of commission or in the hands of receivers.

The greatest change in the fish-scrap industry of the last 25 years has been the introduction within recent years of improved machinery for manufacturing the scrap. The success of this move has been pronounced. This success has been almost too recent to enable one to say what effect it will have on the industry. But since the main expense involved in the industry lies in the operation of the boats and the main profit in the success of the boats, it is evident that changes in the factory proper can not have a far-reaching influence on the industry as a whole.

IN THE LIGHT OF THE SUPPLY OF FISH.

Repeated inquiries among the menhaden fishermen with respect to the decrease in the number of fish have failed to reveal any important indication that the menhaden are any less abundant to-day than in times past. Occasionally the opinion is expressed that they have decreased; but frequently this opinion is based on the disappearance of the fish from certain inclosed bodies of water from entering which they are prevented by the large number of fishing steamers operating at the entrance to such bodies of water. As has been pretty conclusively indicated, the number of fish caught by the fishermen is hardly significant when compared with those destroyed by the carnivorous fish which prey upon them. It is not to be expected, therefore, that even increasing fishing will impair their numbers, unless, indeed, cer-

tain movements or habits of the schools, which in the past have served to protect them from their predatory foes or have enabled them to reproduce, are interfered with by the fishermen. If fishing off the entrances to the various bays and sounds along the coast prevents the menhaden from entering these waters, this fact may assist in their destruction by keeping them on the high seas, where, presumably, they are more open to attack than when feeding in the more sheltered bays and river mouths.

So long as the fish are not interfered with at the time of their spawning season, however, there is little danger of their number being impaired seriously by man, since their rate of reproduction is so enormous. It is maintained that but few spawning fish ever are caught by the fishermen, and that the spawning season begins at about the time the fishing season ends. This is not quite true of the season in North Carolina, where the fishing season and spawning season overlap, and is open to doubt at other places. While many fish are caught containing roe, so few are taken from which the spawn is running that it is probably true that the spawning of the menhaden is not seriously interfered with.

Doubtless fishing methods will continue to be improved so that more effective fishing will be possible. The development of the fishing end of the industry will have to take place in that direction rather than in an increase in the number of steamers fishing; for the larger the number of the latter, the more will they interfere with each other by frightening and scattering the schools, and to a corresponding degree will they impair each other's efficiency. Since the operation of the steamers is the most important part of the industry, a fair catch is imperative if the industry is to pay.

It frequently has been suggested that the number of menhaden could be increased by decreasing the number of their foes. This is doubtless true; but if the number of the menhaden is not appreciably decreased from year to year by the most vigorous fishing, it would appear equally impossible to decrease their foes by applying the same method. Something, possibly, could be accomplished by attacking the predaceous fish at their spawning beds. Since the most important of the predaceous fish, excepting the dogfish, are among those highly valued for food, it would scarcely be feasible to destroy these food fish to preserve the others commonly not so regarded.

The number of menhaden now available doubtless represents a state of equilibrium between their natural tendency to multiply by procreation and their destruction by the hordes of other fish whose main food they constitute. This equilibrium doubtless has existed for ages. It is improbable therefore that it will now be upset by any natural cause.

A word of warning, however, should be given those operators whose crews take menhaden in the late fall and the winter, that if they catch spawning fish they are running the risk of decreasing the supply. Serious interference with the fish at their spawning season means the inevitable depletion of the schools.

IN THE LIGHT OF THE FUTURE DEMAND FOR NITROGEN.

Certainly it is true that there will continue to be a use for nitrogen compounds for fertilizers for many years to come, and that for a time, at least, this use will be a rapidly increasing one. Whether there always will be such a demand is impossible to say and idle to speculate. The understanding of fertilizers and their action in the stimulation of plant growth now is only in its incipiency. Subsequent investigation may show, and doubtless will, that some of our agricultural practices are based on misconceptions. Subsequent investigations may show that certain of the materials now used as fertilizers are not as good as certain others yet to be tested, for it is known definitely that many other substances besides compounds of nitrogen, potassium, and phosphorous produce a stimulation similar, or, at least, analogous, to that produced by the present ingredients of commercial fertilizers regarded as essential.

The general scarcity of nitrogenous compounds has stimulated the investigation of processes for "fixing" the nitrogen of the atmosphere so that to-day there are at least three distinct methods of bringing about reaction between nitrogen and other substances which have been made the base of nitrogen-fixing industries. These are methods for oxidizing the nitrogen of air to nitric acid, for bringing about a union between the nitrogen of air and calcium carbide to form calcium cyanamide, and for inducing a reaction between the nitrogen of air and hydrogen to form ammonia. These industries are only in their infancy, so to speak, having been in operation only a few years. The rapid development of and improvement in the processes, growth in number and size of plants, and corresponding increase in output show that already they are on a satisfactory commercial basis and bespeak for them a successful future. Whether they will find it commercially advantageous or possible to market nitrogenous compounds at a lower price than now obtains or at a price with which the manufacturers of fish scrap can not compete remains for the future to disclose. With an unlimited and easily accessible supply of raw materials and a practically inexhaustible source of power for operation

the manufacturers of the atmospheric products certainly are in a position to supply immense quantities of nitrogenous fertilizers.

The present great source of combined nitrogen in this country is ammonium sulphate from the by-product coke oven. The unrecovered ammonia, liberated in the old form of coke oven, the beehive, is more than enough to supply the fertilizer trade with all the fixed nitrogen it demands. Should this amount be rendered available by a sudden improvement in the coking process, the preparation of fish scrap for fertilizer use doubtless would become commercially infeasible. It is more probable that the increase in the output of ammonium sulphate will keep pace with the increase in demand therefor, and that the price fluctuations will be gradual and slight.

In recapitulation, then, it may be said that while the demand for nitrogen compounds of animal or vegetable origin undoubtedly will continue to increase, the prospects for the supply of inorganic nitrogenous compounds are quite bright. While the fertilizer industry, perhaps, prefers the former, it is quite independent of them so long as the supply of the latter is ample. So, should the price of fish scrap be increased, it appears probable that increased amounts of ammonium sulphate, and, in the future, atmospheric products would take its place. In the light of these considerations, then, it does not appear reasonable to believe that the demand for and the price offered for fish scrap for fertilizer purposes will materially increase.

IN THE LIGHT OF THE POSSIBLE INCREASED DEMANDS FOR FISH FOR FOOD.

The fact is forced upon our attention daily that the cost of food is increasing. This can only mean either that food is becoming more scarce in proportion to population, or that the expense of getting it to the consumer is increasing, or both. The decrease in the exportation of American food products is an indication that the former is true, and the continued elaboration and extension of the middleman system of handling produce undoubtedly makes the latter true. A number of possibilities may be realized which will operate to increase the abundance and availability of farm produce, so that the increase in production of food can keep pace with the increase in population for a great many years to come. However, should this increase in production not come to pass, the increasing scarcity of food in general, and of nitrogenous food in particular, will make it imperative that the fish of the sea be more economically utilized. This will mean at first a gradual stimulation of the present fisheries engaged in catching the so-called food fishes, especially those whose catches are preserved for shipment long distances and for consumption at times and places in which fresh fish are not available.

The menhaden commonly are regarded as nonedible fish. The fishermen, when asked why the menhaden are not edible, reply that they are "too boney" or "too oily"; others acknowledge that the menhaden, when freshly caught and properly cooked, have as good a flavor as any other fish. It is true that choicer fish are usually at hand and are chosen at the expense of the menhaden, and in that sense they are not edible. In short, it appears undoubtedly true that they are edible and palatable, but are not as choice as a number of other fish usually to be had, and therefore as a usual thing they are not eaten. At times they have appeared in the fish markets of the East and have brought prices comparable with those fetched by other fish recognized as food fish.

In former years it has been the practice among the people inhabiting the coastal sections of the United States to preserve a number of barrels of menhaden in salt for home consumption. At times salted menhaden have been prepared in fairly large quantities for exportation and as a sort of substitute for salt mackerel. This has been true especially in seasons of scarcity of other fish. The statistics of the Bureau of Fisheries of 1905 covering the fishing activities of the New England States show that only 8,600 menhaden, valued at $252, were salted during that year; these were in the State of Massachusetts. Smith[1] has stated that 25,000 menhaden were salted for their own use by the crews of two steamers of the menhaden fleet of 1895. It is presumable that this was not peculiar to these two steamers alone and that a similar practice was in vogue to a proportionate extent on the other 54 steamers and 28 sailing vessels in use that year.

Menhaden have been prepared as sardines and have been declared a complete success when so used. It has been demonstrated that a meat extract can be prepared from their flesh equal in flavor and nutritive value to the well-known extract of beef. While this fact has been known for many years, the process of extraction so far has failed of development on a commercial scale. The extract is said to equal 20 per cent of the weight of the fish. The expressed flesh and the oil are obtainable as by-products, the former for fertilizer purposes and the latter for the uses to which it is now applied. In short, past experience has shown that the menhaden are available as food fish to be used fresh, where marketable, for preserving in oil as sardines, or in salt, as mullets and herring are now preserved, or as a source of meat extract, as the exigencies of the food supply should demand.

At present there is no indication that the consumption of menhaden for food for man is on the increase.

[1] Notes on an Investigation of the Menhaden Fishing in 1894, with Special Reference to the Food Fishes Taken. Bull. U. S. Fish Comm., 1895, p. 285.

IN THE LIGHT OF THE MORE COMPLETE UTILIZATION OF THE WASTE FROM CANNERIES AND OF WASTE FISH.

The aggregate annual waste from the dressing of fish is undoubtedly great. About 25 per cent of the weight of the "round" or fresh fish is discarded in dressing. With the exception of the canneries, there are few places where enough fish are dressed to make the treatment of the cuttings for the preparation of fertilizer economically feasible. Practically all of the small fish to be found on the market fresh are sold "round"; the dressing is done by the individual consumer. The waste thus produced finds its way into the garbage and is disposed of in that manner. In some fishing centers it is the custom to remove the viscera of the fish before marketing, but not the heads. In this case the fish are usually dressed on board the fishing boats and the waste is thrown overboard. Once the habits of the fishermen in this regard are overcome, and a plant for its treatment established at a convenient point of call for the fishing fleet, it is possible that a great deal of this material could be saved and converted into fertilizer. It is the custom at present in this manner of dressing fish to save the livers. The remaining viscera probably are low in their content of oil, possibly too low to make an extraction profitable; and the remainder is of a rather watery nature, containing little solid matter. However, the solid matter that is present is highly nitrogenous and therefore of fertilizer value. Furthermore, it is believed that to throw this material overboard is injurious to the fisheries, causing the desirable fish to forsake the waters thus polluted and attracting large numbers of dogfish inimical to the food fish. This practice is sufficiently undesirable to merit prohibition by law. At the same time, in such a contingency, plants suitable for its disposal should be assured by the same power.

There is a distinct possibility that enough of this product is recoverable at certain points to enable small rendering plants to operate; and at present, it is known to the writer, it is planned to make use in some manner of the offal obtainable from at least one fleet of about 50 fishing boats. But there is not a large enough number of fishing centers where the practices are such as described, nor is there enough material available at any one point to make the amount of fertilizer produced from that source of any great significance.

The cuttings from herring and other fish canned at the center of the fish-canning industry on the Atlantic coast, it has been shown in a previous paragraph, amounted to 36,496 hogsheads, yielding 31 tons of wet scrap in 1895, and an amount of cuttings which gave 50 tons of wet scrap in 1905. While data showing the completeness with which the scrap of that neighborhood is utilized are lacking, it is presumable that since the equipment for its rendering has been installed, all that is readily available is so employed. Similar material

is produced in large amount by the extensive fisheries on the Great Lakes, but there again it is so badly scattered that its treatment to any considerable extent is impracticable. These sources then scarcely can be looked to for increasing the Nation's output in fish scrap.

Among the so-called waste fish, fish commonly regarded as unfit for food and applied to no other use, the dogfish are perhaps most numerous in coastal waters and most easily caught. The interest of the various fisheries rather demand that the number of dogfish be reduced; and the experience in Canada, where through Government initiative they are being converted into fertilizer, shows that they are a potentially large source of fish for fish-scrap purposes, and in their utilization one reasonably may expect a development of the fish-scrap industry.

This discussion has been confined to conditions as they have been observed on the Atlantic coast and do not apply at all to the Pacific coast. The salmon canneries on the Pacific coast produce very large amounts of refuse, representing, roughly, 30 per cent of the "round" weight of the salmon taken. The salmon-canning industry by no means is confined to the States, but is carried on quite extensively in southeastern and southwestern Alaska. A considerable amount of the refuse now produced in the States is made use of in the preparation of fertilizers, a practice which is on the increase. In Alaska practically none of the refuse is saved. A discussion of the salmon-cannery waste is not in place in this report, since it is the intention of this bureau to conduct an investigation during the coming summer with a view to the more complete utilization of this material for fertilizer purposes. Since nature has provided an abundant growth of the self-perpetuating and highly potassic kelp in the neighborhood of many of the canneries, it is hoped that the two materials can be combined and a fertilizer, containing the three most desired ingredients—nitrogen, phosphoric acid, and potash—be manufactured with profit.

OILS.

DEVELOPMENT.

Fish oils for many years have been among the important products taken from the sea. The whale constituted the first important source of the so-called fish oils and to-day yields about 3,000,000 gallons annually. In addition to these, other aquatic animals, such as the porpoise, the blackfish, seals, walrus, and the livers of cod, have been made a fruitful source of the animal oils.

Menhaden oil, the true fish oil, and by far the most important oil produced on the Atlantic coast of the United States, first appeared on the market in considerable quantity in the early sixties. The large prices obtained in the early days of the industry led to a rapid

development in the industry and a consequent overproduction in oil. In the seventies the annual production exceeded 2,000,000 gallons, a figure which it closely has maintained on the average ever since. The annual production since 1873 is given, by years, in Table III, on page 7.

PRICES.

The range in prices since 1863 of the various grades of oil is given in the subjoined table. The data for the years 1863 to 1902 are taken from the report by Stevenson, previously quoted; those for the following years from the Oil, Paint, and Drug Reporter.

During the past year the oil has varied in price from 23 cents to 28 cents per gallon.

TABLE XIII.—*Statement of the range of prices for crude northern menhaden oil in the New York market from 1863 to 1911, inclusive.*

Year.	Lowest.	Highest.	Year.	Lowest.	Highest.
1863	$0.75	$1.00	1888	$0.20	$0.32
1864	1.10	1.35	1889	.21	.32
1865	.80	1.40	1890	.22	.30
1866	.70	1.135	1891	.255	.30
1867	.45	.70	1892	.30	.38
1868	.50	.95	1893	.33	.40
1869	.625	1.025	1894	.21	.33
1870	.40	.68	1895	.19	.25
1871	.35	.55	1896	.18	.23
1872	.36	.65	1897	.18	.25
1873	.32	.605	1898	.225	.24
1874	.35	.475	1899	.225	.27
1875	.305	.485	1900	.25	.27
1876	.30	.50	1901	.26	.30
1877	.30	.46	1902	.26	.29
1878	.23	.45	1903	.22	.27
1879	.24	.35	1904	.21	.25
1880	.29	.43	1905	.17	.21
1881	.30	.395	1906	.24	.26
1882	.32	.42	1907	.....	.....
1883	.35	.48	1908	.24	.27
1884	.26	.475	1909	.21	.30
1885	.21	.30	1910	Contract.	Contract.
1886	.20	.26	1911	.23	.28
1887	.19	.21			

TECHNOLOGY.

The mixture of oil and water running from the cooked fish in the presses is conducted into the first and uppermost of a set of tanks arranged one somewhat above the other. In this vat the mixture on standing a short time separates into a stratum of oil floating on an aqueous layer. The separation may be assisted by heating the mixture. For this purpose steam coils are provided. The oil thence is allowed to flow by a suitable arrangement of weirs successively through the series of receptacles, in which by means of stronger heating by steam it is gradually purified from its contained water and small particles of flesh. The greater part of the fine particles of flesh separate in the first vat, settling to the bottom. This fine mush is known as "gurry," and sometimes is sold to the manufacturers

of soap without further treatment, and in some cases is placed in stout canvas bags and subjected to pressure to recover the oil which it still contains. The residual solid matter is added to the scrap. As this is free from bones, its nitrogen content is correspondingly higher than that of the ordinary scrap.

The oil that has been put through the simple process of separation and purification described is run directly into barrels for shipment or into large storage tanks from which it is drawn off as desired for shipment. It usually is sold in bulk to oil refiners by whom it is prepared for the various uses to which it is adapted.

YIELD.

The yield in oil varies (1) with the year, (2) more decidedly with the locality from which the fish are taken, and (3) most widely with the time of the year when taken. The fish taken in northern waters as a rule are fatter than those from southern waters. "In the year 1900, for instance, the yield of oil at the Rhode Island factories was 5.76 gallons per 1,000 fish; in New York it was 6.39 gallons, in Delaware 4.92 gallons, and in Texas 3.51 gallons to the 1,000 fish."[1] When the fish appear in the spring they frequently are so thin that no recoverable oil at all is obtained from them. The fish taken in the fall, on the contrary, yield on the average 12 gallons per 1,000 and frequently 15 gallons per 1,000. The variation in yield per thousand from year to year, therefore, probably is determined by the relative number of fish caught in the spring and fall.

PROPERTIES AND USES.

Crude menhaden oil varies in color from light amber to dark brown. This wide range in color is due to the variation in the manner of treatment of the fish and the preliminary purification of the oil. Its viscosity is determined largely by temperature.

Formerly menhaden oil was used principally as an illuminant and in currying leather. In addition, it long has been used as a paint vehicle, as a lubricant, and as a soap-making grease. Its use in currying leather and as an illuminant has been supplanted to a considerable extent by that of mineral oils, while its employment in the other manners mentioned has increased. Large quantities now are used in the paint manufacturing industry and in tempering steel. For the latter purpose a large amount is sold directly to the manufacturers of steel articles.

Important contributions to the knowledge of fish oils as paint vehicles have been made by Toch.[2] This paint and oil specialist regards menhaden oil as the best of the fish oils. He differentiates

[1] Stevenson, loc. cit.

[2] Toch, J. Ind. Eng. Chem., 3, 627 (1911).

strictly between menhaden oil and other so-called fish oils, such as those obtained from the whale, porpoise, and seals, as those from the latter three sources lack those qualities possessed by menhaden oil to a marked degree, which would classify them as drying oils. Their admixture with drying oils, such as tung and boiled linseed oils, does not avail, for while they may appear to have dried they become sticky again in the presence of humid air.

In the subjoined table are given the specific gravities and iodine numbers of several oils commonly classed as fish oils. The iodine numbers are determined by the method of Hubl.

TABLE XIV.—*Specific gravities and iodine numbers of fish oils.*

Kind of oil.	Specific gravity at 20° C.	Iodine number.	Kind of oil.	Specific gravity at 20° C.	Iodine number.
No. 1. Crude whale oil	0.9195	136.1	Menhaden oils:		
No. 1. Filtered whale oil	.9168	125.0	Extra bleached winter	0.9237	150.4
No. 2. Filtered whale oil	.9187	142.9	Bleached, refined	.9273	161.2
Cod oil	.9196	147.3	Regular	.9249	165.7
Porpoise body oil	.9233	132.3	Dark brown	.9250	154.5
Seal oil, water white	.9227	143.0			

The authority quoted says further:

The oil that gives the best and most lasting results for paint purposes is the menhaden oil, and the winter-bleached variety is the one that should be recommended. This is an oil fairly pale in color, with an iodine number of 150 or over, and with little or no fishy odor; in fact, I might say that in the purchasing of fish oils for paint purposes it is well to beware of a fish oil that has the so-called characteristic fishy odor. I have not yet satisfied myself as to the cause of this odor, but, so far as I have reached in my investigation, I am inclined to believe it is due to phosphorous decomposition compounds. The results which I have obtained from the proper grades of fish oil—and I am glad to say that there are several manufacturers sufficiently intelligent to market the oils that are very desirable—warrant me in saying that fish oil in the hands of an intelligent manufacturer, and used up to 75 per cent, produces excellent results for exterior purposes. For interior purposes fish oil does not seem to be desirable, for it gives off noxious gases for a long time.[1]

It is recommended that for exterior work three parts of fish oil be mixed with one part of linseed oil. The mixture is nonhygroscopic—when dry it remains dry—and the results obtained with it are described as excellent and lasting. The iodine number, it is maintained, is an index of the suitability of fish oils for paint purposes. It profitably may be substituted for linseed oil in a number of applications. It is more resistant to the action of heat than linseed oil, and hence is especially adaptable to use in painting ironwork such as boiler fronts and smokestacks. It holds up better in a moist climate, such as that existing in proximity to the seashore. Its use is

[1] Toch, loc. cit.

recommended especially for replacing linseed oil in the manufacture of patent leather and similar products and printing ink. The patent leather resulting is more flexible and less liable to crack, though it possesses a somewhat less glossy surface. An objection to its use in this manner, however, is a peculiar efflorescence which its presence causes to form on the surface of the preparation. Its moderate use in the manufacture of baked japans also has been found highly advantageous.

Menhaden oil should, of course, be used with a drier, and for that purpose the best results are obtained by means of a tungate drier. A tungate drier is one in which tung oil, or China wood oil, is boiled with a lead and manganese oxide, and when the solution is complete this is then mixed with a properly made resinate of lead and manganese. Such a drier becomes soluble in the oil at temperatures over 100° C., and hardens the resulting paint very thoroughly. For fabrics, however, fish oil must be heated to a temperature of over 200° C., and if air is injected at such a temperature the glycerides are expelled and thick oil is produced which, in conjunction with the drier just named, is equally good for printing inks. It is advisable, however, to add at least 25 per cent of either a heavy bodied linseed oil or a raw linseed oil which does not break before the manipulation just referred to is begun.[1]

The manipulation requisite on the part of the manufacturers to render their oils immediately usable for paint vehicles involves merely the addition of the drier and boiled linseed oil to the fish oil. The product should be sold directly to the paint manufacturers. The advantages gained are a higher price gotten because of this manipulation and because of the elimination of the middleman, and the assurance which the paint manufacturer has that the oil purchased directly from the manufacturer of fish oils probably is the pure product.

In this connection it should be added that undoubtedly there are certain other ways, and probably many more, in which the value of the menhaden oil easily might be enhanced. The considerable portion of the time when, because the fish-rendering plant is lying idle, the employees are unoccupied, should make it possible for the operators to expend more labor on their oil with a view to the improvement of its quality, and to manipulate it to render it suitable for special purposes, without greatly adding to the cost of manufacture.

[1] Toch, loc. cit.

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A NORMAL DAY'S WORK FOR VARIOUS FARM OPERATIONS.

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INTRODUCTION.

In order that farm work may be planned in advance or performed properly from season to season, it is essential to know what may fairly be expected daily of a workman for each kind of work, of any kind and size of implement, of each unit of power, and of any practicable combination of power, workmen, and tools. Data of this character are peculiarly valuable when a new and unfamiliar enterprise is to be undertaken by the farmer, and particularly where a partial or general reorganization of the farm business is contemplated. Such data are also necessary to insure that adequate labor and equipment are provided for and that the former is occupied to its fullest extent throughout the season, to determine the feasibility of a cropping system or rotation, to plan a practicable distribution of labor, and to insure that normal daily efficiency is secured from man and horse or to make certain that they are not overtaxed. The immediate demand that at least general averages of this character be made available for the farm-reorganization work of the Office of Farm Management has resulted in the accumulation of the data presented in the following pages. Since the normal daily efficiency of equipment and workmen is an element or factor both of the planning and execution of farm work, the average or normal day's work for each operation is referred to in the text and tables as a "daily factor."

RELATION OF FARM EQUIPMENT TO FARM MANAGEMENT.

From the practical standpoint, each individual farm must be considered as a business entity as well as a physical unit, and farm management is concerned with the planning, adjustment, and seasonal manipulation of the elements of farm production (land, crops, live stock, labor, tools, and structures), so that all will mutually operate

to secure the greatest profit without impairing the efficiency of any factor of production. In attempting to bring about and maintain this profitable adjustment, every farmer consciously or otherwise utilizes and is limited by physical and economic factors peculiar to the farming business.

From the investigational viewpoint, the individual farm with its cropping system, practice, equipment, current operations, and general organization is a means to an end, and farm management is concerned with the farm unit only in so far as it affords impersonal data from which general principles can be formulated and applied to farms of its type and the conditions and possibilities of its locality. For purposes of investigation as well as use, the elements of farm equipment which affect the management of farms have been considered in two classes, which are here briefly referred to and defined in order to develop the relation between the science and practice of farm management and the subject matter of this bulletin. One class of elements relates to the investment in equipment and the other to the operation of equipment, the first being termed "investment factors" and the second "operating factors." Operating factors are further classified into "seasonal" and "daily" factors.

INVESTMENT FACTORS.

By assembling masses of data from many farms, covering either the entire organization of each or selected elements only, useful facts and factors not previously known can be made available. As a comparatively simple illustration, let it be assumed that it is necessary to determine the optimum investment to be made in outbuildings for a certain 200-acre farm. It is not safe to depend upon direct mathematical calculation on the basis of the physical needs for farm storage, since the investment is limited by the farm income and the physical demands must be to a certain degree subordinated to the economic. Neither would it be wise to depend upon the example of but one practical farmer who had recently decided the matter for himself, since the individual must have had but little information to guide him and may have made serious errors, such as building in a year of big crops and investing so much that his farm pays no interest on the expenditure, or he may have been compelled to build in a "lean" year and may have invested so little as to be unduly cramped for space and may be incurring losses through damage and inconvenience.

If, however, many 200-acre farms in an area are examined, a normal investment factor, representing a considerable period of time and typical of those farms which are both physically adequate and financially solvent, can be taken as the optimum factor desired. Similarly, the distribution of investment in all classes of equipment can

be obtained. From such data the principles and relationships for wise investment can be worked out, which might possibly be recognized by the occasional individual, but which must at best be apprehended only vaguely by the majority, if they are not quite without the purview of the man confined to the duties and experience of one farm.

SEASONAL OPERATING FACTORS.

Under practical farm conditions, work can be planned intelligently and successfully executed only when allowance is made for rainy days and other climatic conditions which interrupt the various operations in their respective seasons. Conclusive data of this character for any region can be secured only by long-continued observations of the weather in connection with its interfering effect on farm work. However, approximate seasonal factors for farm operations can often be calculated for any locality from the current practice with any crop.[1]

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[1] In the southern part of the corn belt one man with a 2-horse team can plow, harrow three times, and plant 40 acres in corn from about March 10 to May 10. What fraction of this period is available for field work?

A man can plow 1.75 acres, harrow 10 acres, or plant 11 acres per day. Hence, to plow, harrow three times, and plant 1 acre will require—

$$\left(\frac{1}{1.75}+\frac{3}{10}+\frac{1}{11}\right) \text{ day.}$$ To do 40 acres will require $$40\left(\frac{1}{1.75}+\frac{3}{10}+\frac{1}{11}\right) \text{ days.}$$

Another expression for this number of days may be found as follows: The whole number of days from March 10 to May 10 is 61; if F represents the fraction of this period available for field work, then $F\times 61$ is the number of available days. Thus, we have two expressions for the number of days available for field work, and these two expressions may therefore be equated. This gives us the equation—

$$40\left(\frac{1}{1.75}+\frac{3}{10}+\frac{1}{11}\right)=F\times 61.$$

Solving this equation, we find F equals 0.631. That is, 63.1 per cent of the period is available for field work.

The following more general formula, based on the above considerations, is useful in many ways:

$$A\left(\frac{t}{a}+\frac{t'}{b}+\frac{t''}{c}+\ldots\ldots\right)=FS.$$

In this formula A stands for the number of acres of land involved; t, t', t'', etc., represent the number of times the various operations are performed; a, b, c, etc., represent the area covered in a day in each of the various operations performed; F is the fraction of time available for field work; and S is the number of days in the season during which the work must be done.

Another use to which this formula may be put is illustrated in the following problem: Assuming that during March one day in two is available; during April and May, two days in three; that oat land is plowed, harrowed once, and drilled; that corn land is plowed, harrowed three times, and planted; that a day's work is plowing 1.75 acres, harrowing 10 acres, drilling 8 acres, or planting 11 acres of corn; and that the rotation used calls for equal areas of corn and oats; what area of each of these two crops can one man put in between March 1 and May 10? Our formula now becomes—

$$A\left(\frac{1}{1.75}+\frac{1}{10}+\frac{1}{8}\right)+A\left(\frac{1}{1.75}+\frac{3}{10}+\frac{1}{11}\right)=\frac{1}{2}\times 31+\frac{2}{3}\times 40.$$

From this we find A equals 24 acres. That is, one man can plant 24 acres each of corn and oats.

If in the foregoing problem we omit the plowing and harrowing for the oats and simply drill them in the old corn stubble by means of a disk drill, as many farmers do, how many acres can the man put in of each of these crops? For this problem the formula now becomes—

$$A\left(\frac{1}{8}\right)+A\left(\frac{1}{1.75}+\frac{3}{10}+\frac{1}{11}\right)=\frac{1}{2}\times 31+\frac{2}{3}\times 40.$$

Approximate seasonal factors having general application to the States of Nebraska, Iowa, Illinois, and Indiana are presented in Table I, being averages of the best judgment of practical farmers for the respective operations in the States named during the growing season from March to November, inclusive.

TABLE I.—*Approximate seasonal factors for farm work in four States of the Middle West.*

PERCENTAGE OF TOTAL DAYS AVAILABLE FOR WORK AT EACH SEASON.

Operation, weather, etc.	Indiana.	Illinois.	Iowa.	Nebraska.
Spring plowing	64.2	69.0	72.1	75.3
Spring harrowing	60.7	63.8	70.5	71.4
Spring seeding	60.4	63.1	65.7	67.5
Spring corn planting	62.5	68.9	71.1	73.5
Cultivating	73.7	75.1	77.5	79.7
Haying	67.8	68.0	70.1	70.5
Grain harvest	71.8	73.0	74.9	76.5
Corn harvest	74.3	73.0	75.1	76.2
Thrashing	72.5	72.3	72.4	74.9
Potato harvest	64.6	67.0	68.4	70.2
Fall plowing	76.4	78.3	78.5	79.2
Fall harrowing	73.9	73.8	77.2	78.9
Fall seeding	70.5	75.5	75.6	76.2
Husking corn	73.3	79.5	82.3	82.6
State average	69.0	71.3	73.7	75.2

AVERAGE MONTHLY WEATHER CONDITIONS, MARCH TO NOVEMBER, INCLUSIVE.

Normal temperature ° F.	59.0	59.5	55.2	57.5
Normal rainfall inches.	30.6	29.7	29.3	24.0
Rainy days in 1911 (0.01 inch and over)	9.5	8.8	7.8	5.7
Entirely clear days in 1911	12.0	13.9	14.4	15.9
Entirely cloudy days in 1911	8.9	8.3	7.3	5.5
Partly cloudy days in 1911	9.2	8.2	8.7	8.9

It will be observed that, except in four instances, there is a regular increase in the percentage of available time for each operation from Indiana to Nebraska. It will also be seen that there is a regular decrease of rainy days and a regular increase of entirely clear days from Indiana westward, according to the weather records for the season of 1911. The normal rainfall also decreases regularly from Indiana westward for the 9-month period. In each percentage in the table from 50 to 100 estimates are submitted in terms of days

From this we find that A equals 38.8 acres.

Another problem. With the rates of work assumed here it is known that one man can plow, harrow three times, and drill 40 acres of wheat during the months of August and September. What is the percentage of available time. For this problem we have—

$$40\left(\frac{1}{1.75}+\frac{3}{10}+\frac{1}{8}\right)=\mathrm{F}\times 61.$$

This gives F equal to 65.3 per cent, or practically two days in three.

In all cases where the area is known on which a man can perform certain operations within a given period—that is, when the seasonal duty of a man is known—the use of the above general formula enables us to determine the average percentage of available time for the season and locality concerned.

A very good way of determining the percentage of available time during the early summer is to ascertain the area of corn or other cultivated crop one man can till, the area he can till in a day, and how often the crop should be cultivated. Thus, in the corn-belt States one man can till 40 acres of corn. He can cultivate 6 acres a day, and the corn should be cultivated once every 10 days. From these facts it follows that $40\left(\frac{1}{6}\right)=\mathrm{F}\times 10$; whence, $\mathrm{F}=\frac{2}{3}$, which means that two days in three are available.—W. J. Spillman.

available in the respective operating seasons. The farmers reporting used figures of their own choice in expressing their judgment, and the percentages were computed separately from these and averaged. The uniform increase in available working time from Indiana westward is so in harmony with the weather conditions recorded by the Weather Bureau that any deviation from the true seasonal factors for these States must be common to all of the figures in the table. While Table I is presented here only for purposes of illustration and definition, it also suggests a rapid method for arriving at general seasonal factors for farm work in any locality.

DAILY OPERATING FACTORS.

Methods of Investigation.

Two methods have been followed in obtaining the data presented in this bulletin. The first, which contemplated extreme accuracy and a long period of study of the subject, was based on personal observations in the field by agents of the Department working in limited areas having uniform conditions. These field observations extended over periods varying in length from 30 minutes to one or more hours. During part of each period the speed in motion was observed under the watch, the length of the speed observation being more or less according to the circumstances which determined convenient distances to be fixed as starting and stopping points. At the same time the agent recorded the entire length of his observation in each case, measured off the acres covered by the workman, and noted the working size of the implement, depth worked, width of rows, distance between turns, kind and condition of soil, amount of power, size of horses, bulk of product handled, and all other factors tending to affect the amount of work performed, so that all data could be compared and variations accounted for. While, in theory, the method of personal and detailed observations should give absolutely accurate and dependable results, because no vital condition is overlooked and the observations are personally and scientifically made, it was found that the variation in observed speed in motion and in surveyed acres per hour in the same area and under identical conditions was quite as wide as the variation in the estimates for a fair day's work by practical farmers reporting for every condition in the United States. It was also apparent from experience with personal observations that these should cover not less than a day and that a very great many of them would be necessary before an average of value could be obtained. The very great cost of the more exact method rendered it available only as a means for furnishing limited data with which to check up results secured by more general and inexpensive methods.

Many of the activities of the Office of Farm Management are predicated on prior experience, from which it has been found that facts

and principles not generally available and often not recognized by those giving the basic information can be deduced from records obtained from farmers. All of the subsequent tables in this bulletin were obtained by taking advantage of this principle. A circular of inquiry covering practically all of the operations of farming was mailed to 25,000 selected farmers distributed throughout every State and Territory. The form was so prepared that every controlling condition affecting any operation, such as the working size of the implement, width, depth, power used, bulk handled, etc., was given blank space to be filled in by each farmer according to his practice and the local conditions with which he was familiar. The answers, therefore, as a whole represented the best judgment in the light of long experience of those who cooperated by sending in replies. Incidentally, since the method permitted each correspondent to record his own local practice, much supplemental information relating to farm equipment and farm management not contemplated by the inquiry was furnished. These features are discussed in connection with the respective tables. The figures represent averages of general conditions in the United States. No attempt has been made to classify the material according to geographic divisions. It is fully realized as regards certain farm operations that the averages of the farmers' estimates from the several agricultural regions are not strictly applicable to any particular district. When sufficient data are obtained from each distinct region, complete tables will be compiled that will take into account differences existing in the time requirements for the several farm operations.

On account of certain conditions affecting the method by which the data in the following tables were obtained, it is believed that many of the averages are too high. While an equal number of inquiries were sent to each State in the Union, the majority of the replies came from the North-Central States, where climate, topography, and short seasons tend relatively to increase the daily duty for farm workmen beyond the average. Again, in making estimates of this character, the human tendency to recall only the exceptionally large day's work rather than the unnoticed normal, or average, would also operate to raise the figures. A third influence tending to raise the estimates would be the natural desire of the correspondent to report a generous amount of work as within his own capacity. Still a fourth influence would be the desire to set high standards for hired help. On account of these biased influences, which are all one sided, it was deemed advisable in presenting the original data of the tables to also include adjustments representing considerable reductions from the reported averages, since for the practical purposes to which these tables will be put it is wiser to use factors which are too low than to make farm plans with factors that are too high. Reductions from

5 to 20 per cent have been made in some of the tables, although some are presented without such adjustments. These adjustments are noted in connection with the respective tables.

Determining the Net Working Day.

In order that the factors obtained might be brought to a uniform basis and so be comparable throughout and with other and similar data, the inquiry was so worded as to develop the net hours actually in the field or at work, during each operation. The time employed in making ready, hitching and unhitching, going and coming, and for meals, has been subtracted and a net working day established in terms of which the respective operations are tabulated and discussed. The respective net hours worked are given in the heading of each appropriate table.

Analysis of the Data.

In the following tables only a small part of the total number of averages for each operation, respectively, is included. Original averages are given in each table only for those widths, sizes, crews, teams, etc., for which the largest numbers were reported. Adjustments and scales of allowances are then included in the respective tables from which the work factor for any feasible width, depth, team, or crew can be computed, using the average for the most common unit of equipment as the standard. These adjustments and allowances are based in each case upon analytical tables covering the entire number of reports for the respective operations. In this analysis the original data were tabulated in every pertinent arrangement and factors deduced for each variation in working size of implement, load, crew, and team. From these deduced factors the scales of allowances in the tables have been derived. The analytical tables referred to were too extensive to be included in this discussion. They covered several groupings each for reports on 1,852 walking plows, 1,056 sulky plows, 822 gang plows, 2,075 spike-tooth harrows, 823 spring-tooth harrows, 1,670 disk harrows, 442 fertilizer drills, 860 manure spreaders; 984 reports on spreading manure from a wagon box with a fork, 597 on spreading manure from piles with a fork, 765 on loading, hauling, and dumping manure in piles, 973 on loading manure into spreader, 112 on spreading lime from piles, 119 on spreading lime from a wagon box, 480 on scooping grain into a wagon, 1,014 on milking cows, 105 on picking strawberries, 626 on digging and picking up potatoes by hand, 110 on digging Irish potatoes with a an ordinary plow, 1,375 on picking up Irish potatoes after an ordinary plow, 429 on picking up Irish potatoes after an elevator digger, 38 on digging sweet potatoes with a sweet-potato plow, 334 on hauling potatoes from field to cellar, 306 on planting Irish potatoes with a

planter, 534 on marking potato rows, 925 on dropping potatoes by hand, 840 on covering seed potatoes, 382 on picking apples, 2,358 on grain binders, 771 on stacking grain from shock, 199 on harvesting grain with header, 1,650 on shocking grain, 153 on thrashing flax, 80 on thrashing alfalfa or clover, 48 on thrashing timothy, 782 on thrashing oats, 895 on thrashing wheat, 760 on harvesting corn with a corn binder, 221 on harvesting corn with a platform cutter, 356 on cutting and shocking corn by hand, 679 on tying and shocking corn after a binder, 778 on husking corn from the shock, 689 on husking standing corn continuously, 969 on husking, hauling, and unloading standing corn, 1,750 on cultivating, 318 on digging Irish potatoes with a digger, 169 on cutting seed potatoes with a cutter, 760 on cutting seed potatoes by hand, 1,493 on grain drills, 1,224 on land rollers, 1,722 on planting corn and cotton with a planter, 386 on planting corn with a hand planter, 358 on planting sweet potatoes, cabbage, and tomatoes by hand, 100 on bean planters, 573 on broadcast seeders, 145 on knapsack sowers, 212 on wheelbarrow sowers, 100 on spreading lime with a spreader, 160 on spraying fruit, 157 on spraying field crops, 2,320 on mowing hay, 2,105 on raking, 539 on hay tedders, 1,122 on cocking hay, 415 on stacking hay with sweep rakes, 459 on stacking hay without sweep rakes, 1,019 on hauling hay from cocks to a barn, 407 on hauling hay using a hay loader, 427 on baling hay with sweep power, 213 on baling hay with an engine, 226 on plowing with a traction engine, and 4,402 on hauling produce to market.

A Normal Day's Work for Given Farm Operations.

PLOWING.

Out of 1,852 reports for walking plows 31 per cent use a 14-inch implement, 27 per cent the 12-inch, about equal numbers use the 10 and 16 inch sizes, and only 19 per cent use other sizes than these. Nearly twice as many report a depth of 6 inches as are reported for any other depth, while nearly equal percentages are reported for 5, 7, and 8 inch depths. This fact may be accounted for by the general tendency of the human mind to employ round numbers in discussing magnitudes not exactly known. In this case the actual practice of farmers, if known, would doubtless cause these percentages to be so distributed as to increase that for 5 and 7 and somewhat reduce that for 6 inch depths. Teams of two horses are used by 73 per cent of farmers. The 3-horse teams are used chiefly on the 16-inch widths and on the 14-inch widths when plowing 7 or more inches deep.

When the walking-plow data were arranged by widths with the depths averaged it was seen that the depth decreased as the width

was increased. This was less pronounced with three horses than with two. Only the 10, 12, 14, and 16 inch widths had sufficient numbers reported to warrant conclusions. A progressive increase in the work done per day and per horse appeared as the width increased, but a much smaller increase per 1,000 pounds of horse was evident, since the heavier horses were used on the wider plows. With a 2-horse walking plow the average load is about 35 square inches in cross section, and 0.72 acre is required daily of each 1,000 pounds of horse.

With the 3-horse teams the depth averaged greater except in the case of the 16-inch width, which showed a smaller average depth than the 2-horse plow of the same width and a much greater acreage daily, as would be expected. Variations from what would normally be expected in the averages for these principal widths could nearly always be explained by some other features of the data, a consideration which augurs well for the unbiased method used in assembling the material and the general accuracy of the results obtained. With a three-horse walking plow the average load was about 25 square inches in cross section and 0.65 acre was required to be plowed daily by each 1,000 pounds of horse.

Where the data for walking plows were arranged by depth with averaged widths, only the 4, 5, 6, 7, 8, and 10 inch depths contained sufficient numbers in the averages to give them value. There was a progressive decrease in the daily acreage as the depth increased, while peculiarities in the figures were accounted for by other elements of the table. Thus, the daily acreage for the 2-horse, 5-inch depth was greater than that for the 4-inch depth, but the width was 0.72 inch greater and the horses considerably heavier. The averages per 1,000 pounds of horse showed about the same decrease in the daily acreage with the increasing depth as did the acreage per horse, since the horses reported for each depth weighed nearly the same, although there was a slight tendency to increase the weight of the horses for the greater depths.

In Table II the reported acreages for walking plows at the 6-inch depth have been arranged by the widths of plows reported and by the number of horses in the team. Adjusted factors for each reported width at the 6-inch depth have been computed and appear in the fourth column opposite the respective plowing units. In the fifth column is a scale of allowances for other depths than 6 inches for each width of plow, expressed in decimal parts of an acre. In the sixth column is shown the depths that can normally be plowed with each width and team without overloading. From columns 4 and 5 the daily duty for any width of plow at any desired depth can be ascertained. Thus, if it is desired to know what may fairly be expected of two horses with a 14-inch plow cutting 9 inches deep,

the daily duty is readily found by subtracting from 1.80, the allowance, 0.12 acre, multiplied by the difference between 9 and 6, giving a work factor of 1.44 acres.

TABLE II.—*A normal day's work with a walking plow, giving the daily acreages reported at 6-inch depths for each width, adjustments for these widths, and a scale of allowances for other depths.*

[Net hours in the field, 9.65.]

Team and width.	Plowed per day.	Number averaged.	Adjusted acreage.	Allowance per inch in depth.	Practicable depths.
Two-horse teams:	*Acres.*			*Acres.*	*Inches.*
8 inches	1.69	18	1.50	0	3 to 12
10 inches	1.62	64	1.60	0	3 to 12
11 inches	1.67	19	1.65	0	3 to 12
12 inches	1.76	143	1.70	.10	3 to 10
14 inches	2.00	151	1.80	.12	3 to 9
16 inches	2.11	22	1.90	.15	3 to 8
Three-horse teams:					
8 inches	1.50	1	1.70	0	3 to 12
10 inches	2.10	5	1.90	0	3 to 12
11 inches	1.50	2	2.00	0	3 to 12
12 inches	2.40	10	2.10	0	3 to 11
14 inches	2.32	38	2.30	.10	3 to 10
16 inches	2.77	65	2.50	.12	3 to 9

From the tabulation of 1,056 reports on sulky plows it appears that that implement is not in such general use as the walking plow, only half as many of this type being reported. A considerable number reported the 18-inch width, while the 12, 14, and 16 inch widths are the most popular. A 16-inch sulky is used by 57 per cent, the 14-inch by 23 per cent, while only 20 per cent use other widths. As in the case of the walking plow, there was concentration on the 6-inch depth, the percentage for which was the same for both walking and sulky plows, while for depths greater than 6 inches the sulky plows show a smaller percentage than the walking plows. Of those reporting, only 12 per cent plow at depths other than 4, 5, 6, 7, 8, and 9 inches with this implement. It was also found that 76 per cent of sulky plows are drawn by three horses and 10 per cent by four horses. The draft of the implement is so great that only 12 per cent of the users attempt to operate it with two horses. The sulky plow is used for cutting wider furrows, but not for such deep plowing as is the walking plow.

When the data for sulky plows were grouped by widths with the depths averaged it was seen that the acreage plowed increased as the width increased and that heavier horses were used on the greater widths. The average load required of each 1,000 pounds of horse was 34 square inches for 2-horse teams, 25 square inches for 3-horse teams, and 21 square inches for 4-horse teams. The respective acreages plowed by these teams per 1,000 pounds of horse was 0.71, 0.72, and 0.64. A team of two horses is necessarily overloaded by a sulky plow, and four horses are not economical except on very hard or unsubdued land.

When the sulky plow data were grouped by teams working at reported depths with the widths averaged, the width decreased as the depth increased and the same was true of the acreage per day and per horse. On account of the greater width of sulky plows as compared with walking plows, the cross section increases rapidly with increased depth, thus limiting the implement to more shallow work with a given amount of power. When four horses are used, the acreage per 1,000 pounds of horse was practically the same at all depths reported, indicating that a cross section of about 26 inches and a daily acreage of 0.65 acre is a comfortable and reasonable task for each 1,000 pounds of horse with this implement.

Comparison of the data for walking and sulky plows indicated that for the same widths and depths with the same number of horses in the teams the sulky plow is somewhat more efficient than the walking plow from the standpoint of area covered in a day, but that the sulky type is limited to more shallow plowing.

In Table III the data for sulky plows have been brought together by horses in the team and under each team the averages for the 6-inch depths are given for the 12, 14, and 16 inch widths. This table is in all respects similar to Table II. The daily duty of any team, width, and depth can be ascertained by inspection of the fourth and fifth columns.

TABLE III.—*A normal day's work with a sulky plow, giving the daily acreages reported at 6-inch depths for each width, adjustments for these widths, and a scale of allowances for other depths.*

[Net hours in the field, 9.65.]

Team and width.	Plowed per day.	Number averaged.	Adjusted acreage.	Allowance per inch for other depths.	Practicable depths.
Two-horse teams:	*Acres.*			*Acres.*	*Inches.*
12 inches	1.84	11	1.65	0.10	3 to 8
14 inches	1.93	18	1.75	.12	3 to 7
16 inches	2.31	4	1.85	.15	3 to 6
Three-horse teams:					
12 inches	1.93	7	2.20	0	3 to 10
14 inches	2.41	59	2.40	.10	3 to 9
16 inches	2.94	171	2.60	.12	3 to 8
Four-horse teams:					
12 inches	3.00	1	2.30	0	3 to 12
14 inches	2.83	6	2.50	0	3 to 12
16 inches	3.19	25	2.80	.10	3 to 10

Compilation of the data for gang plows indicated that 58 per cent of the gang plows used have 14-inch bottoms, 30 per cent use two 12-inch bottoms, while only 12 per cent use other sizes. A limited number use a light gang with two 10-inch bottoms. It was seen also that deep plowing is practiced less with gang plows than with sulky plows, 29 per cent reporting 5 inches deep, which percentage would doubtless be largely increased if correction were made for concentration on the 6-inch depth. Less than 2 per cent reported depths

greater than 8 inches, whereas for the walking, sulky, and gang plows, respectively, the percentage plowing at 8 inches deep is 17, 12, and 5. Four horses are used by 58 per cent, five horses by 25 per cent, and six horses by 10 per cent. Many find it necessary to use more than six horses where the same horses work all day or on very heavy plowing. In the Central West gang plowing is often done with four horses working half days alternately. This inquiry has not separated these from the general averages in the table, since it was not feasible to provide space for this practice in the blank on which the information was obtained.

When the gang-plow data were brought together by widths with averaged depths and vice versa, it would seem that the users of the wider plows had heavier horses and also did not plow so deep. With increased power at a given width, the depth increased. In general, the depth decreased as the width increased, while the acreages per day and per horse increased, and conversely. The analysis indicated that each 1,000 pounds of horse is loaded with 29 square inches in a cross section of the furrow with four horses, 25 square inches with five horses, and 23 square inches with six horses, and that these teams plow 0.86, 0.79, and 0.68 acre per day per 1,000 pounds of horse, respectively.

A comparison of the reported acreages per 1,000 pounds of horse for sulky and gang plows indicates that the gang plows are somewhat more efficient when working at the same widths and depths. The fact that a smaller proportion of farmers use 4-horse teams on gang plows than use 3-horse teams on sulky plows indicates that four horses are much overloaded by a gang plow. This conclusion is also borne out by the fact that plowing deep is not so general with gang plows, as well as by the general opinion of farmers in regions where gang plows are used. The operation of plowing is a severe tax on horses, but its magnitude and cost encourage the tendency to load them to the limit of their capacity. The greater acreages plowed by the gang type are due in part to the more level land, to freedom from obstructions in the soil, and to the greater speed required of horses in the sections where sulky and gang plows are used. They may also be accounted for by the mechanical construction of the sulky frame, which makes it possible to hold the plow to its rated or other desired width more uniformly than can be done with walking plows when the horses are overloaded. In plowing, anything over 25 square inches in cross section and 0.65 acre daily per 1,000 pounds of horse appears generally to be an overload.

In Table IV data for gang plows have been compiled in a manner similar to that for Tables II and III. The daily duty for any desired unit of equipment and depth can be readily ascertained by inspection of the fourth and fifth columns.

TABLE IV.—*A normal day's work with a gang plow, giving the daily acreages reported at 6-inch depths for each width, adjustments for these widths, and a scale of allowances for other depths.*

[Net hours in the field, 9.65.]

Team and width.	Plowed per day.	Number averaged.	Adjusted acreage.	Allowance per inch for other depths.	Practicable depths.
Four-horse teams:	*Acres.*			*Acres.*	*Inches.*
24 inches	4.23	71	4.00	0.12	3 to 8
28 inches	4.72	73	4.25	.15	3 to 7
Five-horse teams:					
24 inches	5.00	8	4.50	.10	3 to 9
28 inches	5.14	69	4.80	.12	3 to 8
Six-horse teams:					
24 inches	4.50	4	4.75	0	3 to 10
28 inches	5.05	31	5.25	.10	3 to 10

Limited data on plowing with traction engines have been assembled in Table V by the rated horsepower of the engines used. In the last column of the table the adjusted factors have been included, these being based on the average efficiency of the total number reporting, then weighted according to the rated horsepower opposite each, respectively, in the first column, and finally reduced 10 per cent. With this type of equipment the total day in the field is from 1 to 1½ hours longer than with horse-drawn plows, while the time actually in motion with engines is nearly as long as the entire day in the field with horses. The depths at which the traction outfits work is considerably less than the practice with the ordinary plows in the humid sections. On sod, the width of cut is less and the depth plowed is about two-thirds of that on stubble. From 20 to 25 per cent greater areas can be plowed daily with the same equipment on stubble than can be turned in sod. From average compilations it appears that the daily efficiency of tractors in plowing is about 0.90 acre on stubble and 0.70 acre on sod for each unit of rated power, while the load for each unit of power is 31 square inches in cross section on stubble and 20 inches in breaking sod.

TABLE V.—*A normal day's work in plowing stubble and sod with traction engine, giving the average acreage reported, according to the horsepower of tractor.*

PLOWING STUBBLE.

[Net hours in the field, 10.97; net hours in motion, 9.25.]

Horsepower of engine.	Width of cut.	Depth.	Reported acreage.	Number averaged.	Adjusted acreage.
	Feet.	*Inches.*			
15	7.4	5.9	15.4	5	12
20	7.9	6.2	18.4	20	16
22	9.7	5.8	21.0	14	18
25	11.3	6.0	22.6	54	20
30	11.5	6.2	24.7	33	24
32	14.6	6.3	32.5	26	26
40	15.3	5.6	33.3	11	32
45	10.0	5.9	22.0	13	36
60	12.3	7.0	27.2	12	42

TABLE V.—*A normal day's work in plowing stubble and sod with traction engine, giving the average acreage reported, according to the horsepower of tractor*—Continued.

PLOWING SOD.

[Net hours in the field, 11.32; net hours in motion, 8.83.]

Horsepower of engine.	Width of cut.	Depth.	Reported acreage.	Number averaged.	Adjusted acreage.
	Feet.	*Inches.*			
15	5.2	4.4	10.3	4	9.7
20	6.1	4.4	13.5	16	13.0
22	7.9	4.2	15.7	12	14.3
25	9.8	4.4	18.3	43	16.2
30	9.7	4.5	20.3	27	19.5
32	13.0	4.7	27.0	24	20.8
40	13.8	4.3	28.2	11	26.0
45	8.4	4.5	17.2	10	29.2
60	9.3	5.4	18.0	6	35.0

HARROWING.

Data were accumulated on the operation of harrowing with the spike-tooth or smoothing type, the spring-tooth type, and the disk or pulverizing type. With the spike-tooth harrow it appears that 41 per cent of farmers use two horses, 29 per cent use four horses, and 23 per cent use three horses. Only 7 per cent use other numbers of horses in their teams. The most popular width of harrow is 10 feet with 17 per cent, the 8-foot width being second with 15 per cent. In other sizes, from 4 to 26 feet, the percentage in use is quite evenly distributed between the limits of 4 to 7 per cent. The draft of this implement is comparatively light for its width, so that the harrowing of large areas daily or the careful preparation of smaller areas is possible and economical.

Analysis of the data showed that on freshly plowed land about 20 per cent less can be covered per day than on well-packed fields. The average area reported for 3-horse outfits was less than would be expected from an increase of 50 per cent in power, but the width was not increased in proportion. With the four horses the width reported averaged more than twice that of two horses and showed an acreage more than 100 per cent greater. With the spike-tooth harrow, which is an implement of comparatively light draft, those farms which can economically utilize more horses in the team throughout the season can also secure greater efficiency per horse in harrowing than is commonly obtained by the majority who use the smoothing harrow with one or two horses. When the data for spike-tooth harrows were consolidated by widths, it was seen that the acreage covered per day per horse and per foot in width increased directly in proportion to the width. In general, each foot in width of the harrow should cover from 1.5 to 1.75 acres daily, and each horse could be loaded with 4½ feet in width and go once over from 6 to 6.5 acres without inconvenience on freshly plowed land. On well-packed land each foot in width should harrow from 1.75 to 2 acres and each horse could be expected to work from 7.25 to 8 acres.

In Table VI the original data for the most common widths of spike-tooth harrows are tabulated by horses in the team. Adjusted acreages have been computed for these widths and allowances indicated for other widths. From an inspection of this table the daily duty of any spike-tooth harrow unit and team can be readily ascertained, as well as the limit of feasible width for the respective teams.

TABLE VI.—*A normal day's work with a spike-tooth harrow, giving the average acreages reported for the widths most frequently used and adjustments for other widths.*

[Net hours in the field, 9.65.]

Number of horses.	Width of harrow.		On freshly plowed land.				On well-packed land.			
	Range.	Most common width.	Harrowed per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.	Harrowed per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.
	Feet.	*Feet.*	*Acres.*			*Acres.*	*Acres.*			*Acres.*
2	4–12	8	10.8	224	9.50	1.2	12.9	194	11.5	1.5
3	8–16	10	15.3	149	13.5	1.5	19.0	140	17.5	1.8
4	10–26	16	28.3	112	25.0	1.8	35.1	102	32.0	2.0

Analysis of the data for spring-tooth harrows indicated that 49 per cent of farmers use two horses, 33 per cent use three horses, and 11 per cent use four horses. The 6-foot harrow is used by 38 per cent, or twice as many as use any other width, while about equal percentages use 5, 7, and 8 foot widths, and very limited numbers use any other size. Since the widths used in spring-tooth equipment (Table VII) average only half that of spike-tooth harrows, it appears that the draft of this type of implement on the soils where it is used is twice that of the smoothing harrow on the soil where the latter is found practical. The spring-tooth harrow is better adapted to stony soils, where the ordinary harrow would not work well. For 2-horse, 3-horse, and 4-horse teams the acreage per horse decreased somewhat and the acreage per foot of width increased to some extent as horses were added, indicating that a width over $2\frac{1}{2}$ feet per horse is generally an overload. On freshly plowed land each foot in width should cover from 1.2 to 1.5 acres daily and each horse could conveniently draw from $2\frac{1}{4}$ to $2\frac{3}{4}$ feet in width and cover 3 to 3.25 acres. On well-packed land each foot in width could be expected to cover from 1.4 to 1.7 acres daily and each horse from 3.5 to 4 acres. About 20 per cent less can be done on freshly plowed than on well-packed soil. This is doubtless due more to the poor footing and consequent high stepping, which tires the horses, than to any difference in draft. With increasing width the daily duty of spring-tooth harrows increases only half as fast as that of the spike-tooth harrow.

In Table VII the original data for the most common widths have been brought together by horses in the team. The table is parallel

in all respects to Table VI for spike-tooth harrows. The duty of any team and width can readily be found by inspection. In using these tables it should be borne in mind that the widths most commonly used have doubtless been found from experience to be the most efficient, so that the factors for other widths, if required in practice, would doubtless be underloads in the smaller sizes and overloads in the larger sizes.

TABLE VII.—*A normal day's work with a spring-tooth harrow, giving the average acreages reported for the widths most frequently used and adjustments for other widths.*

[Net hours in the field, 9.65.]

Number of horses.	Width of harrow.		On freshly plowed land.				On well-packed land.			
	Range.	Most common width.	Harrowed per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.	Harrowed per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.
	Feet.	*Feet.*	*Acres.*			*Acres.*	*Acres.*			*Acres.*
2	4–8	6	7.4	180	6.5	0.60	8.6	169	7.5	0.70
3	6–10	6	8.2	120	7.4	.70	10.2	113	9.2	.80
4	6–12	8	13.1	22	11.8	.75	14.8	23	13.3	.90

Compilation of the data for disk harrows showed it to be an implement of very heavy draft, since 52 per cent of farmers find it necessary to use four horses on an implement which is not frequently found in widths over 8 feet. This width is one-half that of the largest practicable size in the spring-tooth type and one-fourth that for the largest spike-tooth harrow. The relative draft per foot of these implements appears to be in the proportion of 4, 2, and 1. About the same proportion, 23 per cent, that report using two horses with the spring and spike tooth harrows use three horses in disking. The 8-foot width is somewhat more generally used than the 6-foot width and 75 per cent of the disk harrows reported are from 6 to 8 feet wide. The 16-inch disk is most generally used; 17 per cent have the 18-inch type, and a somewhat smaller proportion use the 12, 14, and 20 inch sizes. Well-packed land is about 20 per cent easier to disk than freshly plowed land from the standpoint of acreage covered in a day. When the power is increased, the average acreage per day increases, while the acres per horse tends slightly to decrease and the acres per foot of width increase, indicating an overload by this implement with the smaller numbers of horses. The area disked by 3-horse teams does not increase over that by 2-horse teams in the proportion that the acreage for four horses increases over that for two horses. The same variation appears as between the 4-horse and 5-horse teams when compared with the difference between 4-horse and 6-horse teams. This is in part explained by the fact that the widths reported for the three and five horse units do not increase in

the same proportion as the power, and in part by the apparent inefficiency of 3-horse and 5-horse hitches and the difficulty to the average teamster in handling them. In general, each horse was loaded with 2 feet in width and must harrow 2.5 to 3 acres on freshly plowed land and from 3 to 3.75 acres daily on well-packed land. The duty of each foot in width of harrow is from 1.3 to 1.5 acres daily on freshly plowed land and from 1.5 to 1.8 acres on well-packed land, assuming adequate power at the normal speed of horses.

In Table VIII original data for the most commonly used widths and teams in disking are presented, together with adjusted factors for these widths and a scale of allowances for other widths. The daily duty for any team and width can be ascertained from this table by inspection.

TABLE VIII.—*A normal day's work with a disk harrow, giving the average daily acreage reported for the widths most frequently used and adjustments for other widths.*

[Net hours in the field, 9.65.]

Number of horses.	Width of harrow.		On freshly plowed land.				On well-packed land.			
	Range.	Most common width.	Harrowed per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.	Harrowed per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.
	Feet.	*Feet.*	*Acres.*			*Acres.*	*Acres.*			*Acres.*
2	4–8	6	7.2	159	6.5	0.50	7.5	147	6.7	0.60
3	5–10	6	7.5	163	6.8	.60	9.1	165	8.0	.70
4	6–10	8	12.8	414	11.5	.80	15.4	432	14.0	.90
5	7–10	8	11.3	7	12.0	.85	13.4	7	14.5	.95
6	7–10	8	15.4	16	13.5	1.00	18.0	19	16.0	1.10

ROLLING WITH LAND ROLLER.

The land roller is not an implement of heavy draft, 83 per cent of users finding two horses adequate for a considerable range in width. The 8-foot width is most generally used, while about equal numbers use 6, 7, and 10 foot widths. Widths of 12 and 14 feet are not uncommon. A 3-horse team is used by 6 per cent and four horses by 8 per cent of farmers. Where three or four horses are used, the acreage per horse is slightly less than with two horses. With the 2-horse teams each foot in width covers less area daily than with larger teams, indicating that the latter move on the average somewhat more rapidly than two horses. With land rollers it appears to be economical to use the larger sizes, since more land can be covered in a given time without adding greatly to the work of the available horses. A width of 4 or 5 feet is a reasonable load per horse and 5 to 7 acres daily per unit of power can be normally expected. The duty of each foot in width is from 1.6 to 1.9 acres daily.

In Table IX the original averages for the widths most frequently used, shown in the second column, have been given, together with adjustments for these acreages and a scale of allowances for other widths of rollers. From the table, computations can readily be made for determining the daily duty of any team and width of roller.

TABLE IX.—*A normal day's work with a land roller, giving the average daily acreage reported for the widths most frequently used and adjustments for other widths.*

[Net hours in the field, 9.65.]

Number of horses.	Width of roller.		Rolled per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.
	Range.	Most common width.				
	Feet.	*Feet.*	*Acres.*			*Acres.*
2	5–12	8	13.2	442	12.0	1.10
3	6–14	8	13.5	24	12.5	1.15
4	8–18	8	15.2	37	14.0	1.20

PLANTING OPERATIONS.

With the grain drill the popular sizes range between 4 and 12 feet in width, a greater number, 23 per cent, using the 8-foot width than any other, with the 6-foot width next. Only 9 per cent use three horses with grain drills, two horses being used by 46 per cent and four horses by 41 per cent of farmers. From the general averages it was seen that the acreage per day per foot of width increased with added power, suggesting a slight overload per horse on the smaller drills with 2-horse teams. The larger teams are used on the larger fields. It was found also that with increasing width and power the acreage planted per day increased, except for the 12-foot width, the limit of practicable width from a mechanical standpoint doubtless being approached in this size. In general, each horse can be loaded with $2\frac{1}{2}$ to $2\frac{3}{4}$ feet in width of drill, and should be expected to cover from 4 to 4.5 acres in a day. The duty of each foot in width of drill is from 1.5 to 1.75 acres per day, assuming adequate power. When the grain-drill data were arranged by length of the field it was found that between lengths of 40 and 160 rods there appeared to be no advantage in favor of larger fields. This was found to be true of other data arranged by distance hauled or length of field, indicating, without exception, that within the limits of 40 to 200 rods distance is not a factor in the day's work.

In Table X, for grain drills, the average acreage for the most common widths and teams is presented, together with adjusted acreages and a table of allowances for other widths. From this table reasonable widths of drills for each size of team can be chosen and the daily duty of any width found from the factors in columns 6 and 7.

TABLE X.—*A normal day's work with a grain drill, giving the average daily acreage reported for the widths most frequently used and adjustments for other widths.*

[Net hours in the field, 9.62.]

Number of horses.	Width of drill.		Drilled per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.
	Range.	Most common width.				
	Feet.	*Feet.*	*Acres.*			*Acres.*
2	4–8	6	8.8	239	7.0	1.40
3	6–10	8	11.7	40	10.5	1.50
4	8–12	8	14.0	178	12.5	1.75
6	8–12	8	16.3	6	14.5	2.00

The reported and adjusted data for seeding with a broadcast seeder, a knapsack sower, and a wheelbarrow sower are brought together in Table XI. With the wheelbarrow seed sower the 14-foot width was used by 40 per cent of farmers, the 16-foot width by 23 per cent, and the 12-foot sower by 18 per cent. While the acreage planted daily increased with the increasing width, it was seen that the proportion of increase fell off at the same time, indicating that the 16-foot width approaches the mechanical limit to convenience in manipulation.

TABLE XI.—*A normal day's work in seeding with the broadcast seeder, knapsack sower, and wheelbarrow sower, giving the average daily acreage reported and adjustments for other widths of sower.*

[Net hours in the field, 9.68.]

Implement.	Width.		Seeded per day.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.
	Range.	Most common width.				
	Feet.	*Feet.*	*Acres.*			*Acres.*
Broadcast seeder			13.5	573	12.0	
Knapsack sower			22.3	145	20.0	
Wheelbarrow sower	10–16	14	20.3	82	18.0	1.50

In Table XII there are grouped the original averages for planting corn and cotton in rows 42 inches apart, the most common width. Adjusted acreages are also included and a scale of allowances for each 6 inches difference in width of row. As with other tables in this bulletin, Table XII is based on analytical tables covering the entire number reporting for these operations. It was found that 41 per cent of farmers plant corn and cotton in rows 42 inches wide, while about equal percentages plant in rows 36, 44, and 48 inches apart, respectively. Throughout the country the range is from 10 to 72 inches. In these operations two horses are used by 61 per cent, and 39 per cent use one horse. The 2-row planter is used by 54 per cent and the 1-row planter by 46 per cent. Comparatively few growers use two horses with a 1-row planter, but the meager data for this group indicated that the addition of one horse and the advantage of the

high-wheeled type increase the daily efficiency of the implement from 40 to 90 per cent, making this equipment nearly as efficient as the 2-row planter with two horses. On the 2-row planter it is, of course, necessary to take considerable time in changing the check wire. The 2-row planter with two horses is essentially twice as rapid as the 1-row planter with one horse. With an inexpensive hand planter a man can plant from 60 to 75 per cent as much corn as can be done with a man and one horse using the horse-drawn type of implement.

TABLE XII.—*A normal day's work in planting corn or cotton, giving the average daily acreage reported for the widths of row most frequently used and adjustments for other widths of row.*

[Net hours in the field, 9.67.]

Power.	Planter.	Most common width of row.	Planted per day.	Number averaged.	Adjusted acreage.	Allowance for each 6 inches in width.
		Inches.	*Acres.*			*Acres.*
One horse	One row	42	6.9	226	6.25	0.80
Two horses	do	42	10.9	57	8.75	.90
Do	Two-row	42	13.6	430	12.25	1.25
Hand	Hand	42	4.4	162	4.00	.60

Work factors for planting sweet potatoes, cabbage, and tomatoes by hand are arranged by crews in Table XIII. On account of the limited data for each crop, the data for the three crops are averaged in the table. Planting sweet potatoes can be done somewhat more rapidly than planting cabbage, while tomatoes can be set out somewhat more rapidly than sweet potatoes. The duty of a man at work of this character is not less than 0.75 acre per day. Comparative data for planting these crops with a transplanting machine were not made available because of the limited number reporting transplanters.

TABLE XIII.—*A normal day's work in planting sweet potatoes, cabbage, and tomatoes by hand, giving the average daily acreage for designated crews and adjustments for each crew and width of row.*

[Net hours in the field, 9.85.]

Number of men.	Number of horses.	Width of row.	Planted per day.	Number averaged.	Adjusted acreage.	Allowance for each 6 inches in width of row.
		Inches.	*Acres.*			*Acres.*
1	1	36	1.0	51	0.90	0.10
2	1	38	1.6	61	1.70	.12
	2	32	1.9	60	1.90	.14
3	2	40	2.4	28	2.60	.16

In Table XIV are presented the averages for cutting seed potatoes by hand and with the mechanical cutter, respectively. The cutter does the work somewhat more than 100 per cent faster than it can

be done by hand. Only one practical grower in five used the cutter, however, the majority believing that the certainty of having an eye on each seed piece is worth the extra expense in the cutting. The original averages have been adjusted by reducing them about 12 per cent.

TABLE XIV.—*A normal day's work in cutting potatoes for seed, giving the average number of bushels per day for cutting by hand and with cutter and adjustments for each method.*

[Net hours at work, 9.48.]

Method of cutting.	Cut per day.	Number averaged.	Adjusted work factor.
	Bushels.		
By hand	15.03	760	13.50
With cutter	32.24	169	28.00

The acreages reported for covering seed potatoes after planting are averaged in Table XV according to the number of horses used and these averages adjusted by reducing them about 10 per cent. A 2-horse team covers somewhat more ground than one horse, and 60 per cent of farmers find it more practical to use two horses.

TABLE XV.—*A normal day's work in covering seed potatoes after planting, giving the average daily acreage and adjusted factors.*

[Net hours in the field, 9.53.]

Number of horses.	Covered per day.	Number averaged.	Adjusted factors.
	Acres.		
1	4.63	299	4.15
2	5.96	541	5.35

The averages for the operation of marking off land for planting are grouped in Table XVI by horses in the team and the width most frequently used. These averages are reduced about 10 per cent to give the adjusted acreage in the table, while the allowances for each difference of 1 foot in width were determined from analytical tables. The 3, 3½, 6, 9, and 12 foot widths are in most general use. The wider markers are in the minority, 31 per cent using a 3-foot marker, and 14 per cent a 3½ foot, with smaller percentages for other widths. On the light soils of the Atlantic Coastal Plain, where extensive trucking operations are carried on, the wider markers are in vogue. There appears to be no economy in using more than one horse with markers less than 12 feet wide, although 59 per cent of planters use two horses in this operation.

TABLE XVI.—*A normal day's work in marking rows for planting, giving the daily acreages reported for designated widths and adjustments for each width.*

[Net hours in the field, 9.53.]

Number of horses.	Width of marker.	Width of rows.	Marked per day for each 3 feet in width of marker.	Number averaged.	Adjusted acreage.	Allowance for each foot in width.
	Feet.	*Feet.*	*Acres.*			*Acres.*
1	3–12	3	5.68	89	5.1	0.75
2	3–12	3	6.81	78	6.2	.65

The operation of planting Irish potatoes by hand and with the 1-man and 2-man type of potato planter is reported in Table XVII. Out of 925 reports, 31 per cent name two acres as a reasonable day's work in dropping potatoes by hand and 26 per cent allow one acre. With the potato planter the 2-man type is somewhat slower than the automatic-feed type. The former is in more general use, since planters feel more certain that seed is placed in every hill with the hand-feed type. The picker (1-man) type of planter also tends to spread disease from one seed tuber to another if disease, such as scab, is present. The original averages have been adjusted by reducing them about 10 per cent.

TABLE XVII.—*A normal day's work in planting Irish potatoes, giving the average acreages reported and adjusted factors for each method.*

[Net hours in the field; 9.53.]

Operation.	Number of men.	Number of horses.	Planted per day.	Number averaged.	Adjusted factors.
			Acres.		
Dropping by hand	1		1.98	925	1.8
Planting with planter	1	2	5.48	132	5.0
	2	2	4.91	174	4.4

HANDLING MANURE.

In Table XVIII the operation of hauling and spreading manure with a manure spreader is shown for loads of less than 60 cubic feet and for 60 cubic feet and over. The heavy draft of this implement renders the use of three or more horses necessary in 70 per cent of cases. A 2-horse team is used by 30 per cent, three horses by 45 per cent, and four horses by 25 per cent of those owning spreaders. The larger loads and teams are all reported from the Mississippi Valley region. Fewer of the larger loads can be handled in a day, but with the increased power used they are unloaded more quickly and spread more evenly. From $1\frac{1}{2}$ to $1\frac{3}{4}$ more loads daily can be spread on sod than on plowed land. For practical purposes the original averages have been adjusted and reduced about 10 per cent.

TABLE XVIII.—*A normal day's work in hauling and spreading manure with a spreader, giving the average work factors reported and adjusted factors averaged according to the size of load.*

[Net hours at work, 9.57.]

Item.	Size of load.			
	Below 60 cubic feet.		60 cubic feet and over.	
	Reported averages.	Adjusted factors.	Reported averages.	Adjusted factors.
Horses in team	2.56	2 or 3	2.88	3
Distance hauled, rods	75.4	.....	79.9	.....
Loads on sod	13.9	12.0	13.1	11.0
Loads on stubble	12.7	11.5	11.7	10.5
Loads per acre	7.6	7.5	6.6	6.5
Minutes to load	23.6	30.0	25.9	35.0
Minutes to unload	10.0	15.0	9.8	14.0
Number averaged	320	.....	485	.....

In Table XIX, spreading manure from a wagon box with a fork, it appears that the average time to unload a 42-bushel load of manure is about 28 minutes, irrespective of the distance spread. With the spreader much larger loads can be thrown off in a period of 10 minutes. In this operation 54 per cent of farmers cover a strip 16 feet wide or more with each load, 36 per cent spread from 9 to 15 feet, and only 10 per cent unload in strips less than 9 feet wide.

TABLE XIX.—*A normal day's work in spreading manure from a wagon with a fork by one man, giving the time to unload averaged according to the distance spread.*

Distance spread.		Size of load.	Time to spread.	Number reporting.
Range.	Average.			
	Feet.	*Bushels.*	*Minutes.*	
8 feet or less	6.84	42.6	28.11	88
9 to 15 feet	11.77	42.10	27.98	323
16 feet and over	20.56	43.94	28.54	465

In Table XX the practice of hauling and dumping manure in piles for later spreading by hand is reported. According to 45 per cent, a fair day's work is between 8 and 10 loads a day, the average for all conditions being about 12 loads daily. Farmers who practice this method haul loads averaging from 40 to 45 bushels in bulk.

TABLE XX.—*A normal day's work in loading, hauling, and dumping manure in piles by one man with a team.*

Number of loads per day.		Size of load.	Distance hauled.	Number averaged.	Percentage reporting.
Range.	Average.				
		Bushels.	*Rods.*		
Under 8	5.74	44	99	120	16
8 to 10	9.22	43	77	344	45
11 to 15	12.87	42	69	207	27
Over 15	20.92	42	67	94	12

In Table XXI the subsequent operation of spreading manure from piles previously placed in the field is arranged by the size of the piles, the percentage reporting each size being also given. Comparison of this table with the similar operation of spreading lime from piles (Table XXIII) reveals the same general features. In each an increase in the size of piles is accompanied by a decrease in the number spread and an increase in the number of bushels spread in a day. Piles containing about 6 bushels are most common, while smaller piles averaging 3 bushels each are more frequent than those containing over 10 bushels.

TABLE XXI.—*A normal day's work in spreading manure from piles with a fork by one man.*

[Net hours in the day, 9.57.]

Size of piles.		Spread per day.		Number averaged.	Percentage reporting.
Range.	Average.	Piles.	Bushels.		
	Bushels.				
Under 5 bushels	2.99	199	595	166	37
5 to 9 bushels	5.70	147	842	200	44
10 to 14 bushels	10.18	102	1,047	88	19

In many respects the data for the several operations in handling manure are less satisfactory and lack uniformity to an extent not found in any other operation reported on. For this arduous work there appears to have developed among farmers less definite ideas than might be expected as to what constitutes a fair amount of work for the respective processes. The great variation in the character and weight of the material handled doubtless complicates the problem of forming definite conclusions regarding these operations, while the practice of doing work of this character at times when other work is not pressing doubtless operates to make unnecessary the formation of definite ideas regarding a fair day's work.

SPREADING LIME AND FERTILIZER.

The data for spreading lime by hand from a wagon box are presented in Table XXII, averaged according to the size of load. While the number in the respective averages is limited, the table shows anticipated relations between the size of load and the number of loads handled daily. Those hauling the larger loads are able to spread greater quantities in a day, but can not haul so many loads.

TABLE XXII.—*A normal day's work in spreading lime from a wagon, giving the number of loads daily, averaged according to the size of the load.*

[Net hours at work, 9.48.]

Size of load.		Weight per load.	Spread per day.		Number averaged.
Range.	Average.		Bushels.	Loads.	
	Bushels.	*Pounds.*			
25 bushels or less	22	1,530	201	9.23	24
30 to 40 bushels	34	2,033	261	7.71	45
45 to 50 bushels	49	2,907	321	6.52	35
55 to 75 bushels	64	2,700	495	7.8	10
Over 75 bushels	106	6,000	500	4.72	5

In Table XXIII the operation of spreading lime from piles previously laid down in the field is arranged by size of piles in terms of bushels. The data were too limited to be arranged into more groups than those chosen. The amount spread in a day increases with the amount used per acre, as was the case with spreading manure from piles in Table XXI.

TABLE XXIII.—*A normal day's work in spreading lime from piles, giving the number of piles spread daily, averaged according to the size of the piles.*

[Net hours in the field, 9.48.]

Size of piles.		Spread per day.		Number averaged.
Range.	Average.	Piles.	Bushels.	
	Bushels.			
0 to 1 bushel	1	227	227	40
2 to 5 bushels	3.5	136	477	40
6 to 50 bushels	25.6	35	917	21

The essential features of the operation of distributing lime with a lime spreader and fertilizer with a fertilizer drill are shown in Table XXIV. The original averages for the widths most commonly used are given, these averages being adjusted by reducing about 10 per cent, and a scale of allowances for each difference of 1 foot from the tabulated width has been deduced. The 8-foot lime spreader is somewhat more popular than the 10-foot size. Lime spreaders are drawn by two horses in 75 per cent of cases. With the fertilizer drill the 6-foot width is preferred by 30 per cent and the 8-foot width by 20 per cent of planters, equal numbers reporting the 5 and 7 foot widths, while 81 per cent of fertilizer drills are drawn by two horses.

TABLE XXIV.—*A normal day's work in spreading lime with a lime spreader and fertilizer with a fertilizer drill, giving the average acreages reported for the widths most frequently used, adjusted acreages for these widths, and allowances deduced for other widths.*

[Net hours in the field, 9.81.]

Implement.	Range of width.	Most common width.	Number of horses in team.	Spread per day.	Number averaged.	Adjusted acreage.	Allowance for other widths (acreage per foot).
	Feet.	*Feet.*		*Acres.*			
Lime spreader	4–12	8	2	10.65	20	9.50	0.75
Fertilizer drill	4–10	6	2	8.44	122	7.50	.70
	6–12	8	3	10.40	15	9.35	.70

CULTIVATING.

The averages for cultivating corn, potatoes, beans, cabbage, and cotton, arranged according to the number of horses to the cultivator, are set out in Table XXV. From the standpoint of acreage covered in a day, two horses are about 40 per cent more efficient than one horse. About 40 per cent of those reporting use two horses in cultivating. A 1-horse cultivator can be expected to cover 4 to 5 acres and a 2-horse cultivator from 6 to 8 acres. Cultivating beans and cabbage is slower work than that for corn and cotton on account of the narrower rows and greater care required with these low plants. The original averages have been adjusted by reducing them about 10 per cent. When the data were assembled by widths of row, no marked relation was found between the width and the amount of work done daily. This may in part be explained by the meager number reported for widths other than 36, 42, and 44 inches, and also by the consideration that the width of planted row is not a factor in cultivating, since the entire surface of the field must be stirred, regardless of the interval between the rows.

TABLE XXV.—*A normal day's work in cultivating corn, potatoes, beans, cabbage, and cotton, giving the average daily acreages reported according to the number of horses used and adjustments for each cultivating unit.*

[Net hours in the field, 9.79.]

Crop.	Number of horses.	Cultivated per day.	Number averaged.	Adjusted acreage per day.
		Acres.		
Corn	1	4.8	791	4.30
	2	7.72	448	7.00
Potatoes	1	4.25	403	3.80
	2	6.53	210	5.90
Beans	1	3.87	228	3.50
	2	6.30	163	5.70
Cabbage	1	4.08	220	3.70
	2	6.06	136	5.45
Cotton	1	4.72	112	4.25
	2	7.35	76	6.80

SPRAYING.

The averages for the spraying of fruit trees are shown in Table XXVI by the number of men in the crew for both hand-power and gasoline-power equipment. Striking increases in the number of trees sprayed are shown for each addition to the force of men in the crew, the other conditions for each type of sprayer being comparatively uniform. Greater numbers of trees are reported for the respective crews with the hand-power type than with the sprayer operated by gasoline engine, but the size of the trees for the hand-power equipment is seen to be very much less. In the same table the data for both types of sprayer have been consolidated by height and spread of trees. Increased height is accompanied by a corresponding spread and distance between trees and a reasonably uniform decrease in the number of trees sprayed, the crews being practically the same. There are, of course, many variations in the construction of spraying equipment which affect this operation, such as number of nozzles, leads of hose, pressure used, and type of sprayer. In a more detailed investigation averages in terms of gallons per day or hour, as well as other useful factors, could be made available. Since it was not practicable to cover all of these features in a general inquiry of this kind, further observations are necessary to secure exhaustive data.

TABLE XXVI.—*A normal day's work with an orchard sprayer, giving the average number of trees sprayed daily.*

[Net hours at work, 9.6.]

SPRAYING BY DESIGNATED CREWS.

Type of sprayer.	Number of men.	Capacity of tank.	Height of trees.	Spread of trees.	Number of trees sprayed per day.	Number averaged.
		Gallons.	*Feet.*	*Feet.*		
Gasoline power	1	250	25	28	110	1
	2	180	20	19	191	20
	3	196	20	21	252	24
Hand power	1	50	18	13	54	4
	2	57	20	19	134	89
	3	68	18	16	305	20

NUMBER OF TREES SPRAYED ACCORDING TO THEIR HEIGHT.

Height of trees.	Average spread.	Number of men.	Number of trees sprayed per day.	Number averaged.
	Feet.			
12 feet or less	11	2.4	329	33
13 to 20 feet	17	2.3	182	83
Over 20 feet (average 28.23)	26	2.2	129	51

Limited data for spraying field crops planted in rows with a knapsack sprayer and with a horse-drawn field sprayer are reported in Table XXVII. Knapsack sprayers and poison dusters are used on

truck and small-fruit crops or in young orchards. In spraying with a field sprayer on potatoes and other field crops there appears to be only a slight gain for 2-horse over 1-horse teams, although most users of this equipment employ two horses. A 4-row sprayer will cover from 12 to 14 acres in a day. The reported averages in the table have been adjusted by reducing them about 10 per cent, and the allowances for each difference in width of 6 inches have been derived from analytical tables.

TABLE XXVII.—*A normal day's work in spraying with a knapsack sprayer and field sprayer, giving the average acreages reported and adjustments for widths sprayed.*

[Net hours at work, 9.6.]

Sprayer.	Width sprayed.	Number of rows.	Number of horses.	Acres per day.	Number averaged.	Adjusted acreage.	Allowance for each 6 inches in width (acreage per day).
	Feet.						
Knapsack	3	1	.....	3.04	35	2.75	0.40
Field	11.5	4	1	12.76	66	11.50	.50
	11.0	4	2	13.54	90	12.25	.60

HARVESTING HAY.

In Table XXVIII the original averages for the operations of mowing, raking, tedding, and cocking hay for those widths and teams most frequently used have been brought together. These averages have been adjusted by reducing them about 10 per cent, and a scale of allowances per foot in width for other feasible widths in each case has been erected.

In mowing hay the 2-horse unit is practically universal. In the analytical tables there was a slight increase in acreage per foot of width with increase of the width of the sickle for sizes up to 7 feet. The limit of mechanical efficiency appears to be approached at 7 feet wide.

From 2,105 reports on raking hay it appears that a 2-horse team is about 45 per cent more efficient than one horse when used with rakes of the widths reported. The duty of each foot in width of rake is from 1.45 to 1.60 acres daily. Each horse should cover from 9 to 14 acres. The 8-foot width is the most used with one horse and the 10-foot width with two horses.

In tedding hay with a hay tedder or kicker two horses appear to be 45 per cent more efficient than one, and 82 per cent use 2-horse teams for this work. Each foot in width of tedder should cover from 1.4 to 1.7 acres daily, and each horse could be expected to go over from 7 to 10 acres.

The factor for cocking hay after bunching with a rake is for an average yield for the 1,122 reports of 1.87 tons per acre.

TABLE XXVIII.—*A normal day's work in mowing, raking, tedding, and cocking hay, giving the average acreages reported for sizes most frequently used, adjustments for these sizes, and allowances deduced for other sizes.*

[Net hours in the field: For mowing, 9.52; for raking, 8.44; for tedding, 8.26; and for cocking, 9.12.]

Operation.	Most common width.	Number of horses.	Acreage per day.	Number averaged.	Adjusted acreage.	Other reported widths.	Allowance for other widths per foot.
	Feet.					*Feet.*	*Acres.*
Mowing	5	2	8.85	1,251	8.0	4–7	1.70
Raking	8	1	11.99	238	10.8	6–12	.75
	10	2	17.91	885	17.0	8–16	.80
Tedding	6	1	9.75	36	8.7	5–10	.65
	10	2	15.88	113	14.3	6–12	.85
Cocking (1 man)			6.29	1,122	5.7		

In hauling hay from windrows to barn, using a hay loader in the field, 36 per cent of farmers do the work with three men, 23 per cent with two men, and 14 per cent with four men, while much smaller percentages use larger crews. It also appears that two horses are used by 38 per cent and four horses by 31 per cent, while 42 per cent use an 8-foot, 17 per cent the 6-foot, and 15 per cent the 10-foot loader. From analytical tables it was also evident that the odd man in three and five man crews adds very little to the amount accomplished daily, and also that the hay sling or fork increases the efficiency of the equipment from 30 to 40 per cent. Increases in the number of men or horses are not attended by proportional increases in the amount of work done, the smaller units being most efficient. A relative decrease in efficiency per man or per horse with an increasing size of crew is uniformly found in all of the tables for crew work. In this operation the duty of a man with the organization stated is from 1.5 to 2.5 acres daily when unloading by hand and from 2.25 to 3 acres when unloading with sling or hay fork. The 2-horse and 4-horse crews are most efficient from the standpoint of total acreage cleared daily, odd horses adding very little to the efficiency of the organization. Those crews having only two men appear to be most effective, owing probably to having the proprietor to set the pace, while the larger crews give opportunity for lost motion through help working only for wages and the limited ability of the average farmer to direct the efforts of others as he can his own. When unloading by hand with the equipment under consideration, the duty of each horse is from 1.75 to 2.25 acres, and when the sling is used this duty should be raised to from 2.5 to 3.5 acres per horse per day. Each foot in width of loader should cover from 0.70 to 1 acre when the loads are thrown off by hand and from 1 to 1.4 acres when unloading with sling or hay fork. In the operation of haying, for distances under 200 rods, the tabulation of the data by distance hauled shows no relation between distance from stack or barn and the acreage cleared in a day.

In Table XXIX the original averages for the crews most commonly used in hauling hay from windrows to barn with a hay loader are given, with adjusted acreages for these crews. The adjustments were made by reducing the two-man averages 20 per cent, the three-man averages 15 per cent, and the four-man averages less than 10 per cent. From the adjusted acreages the daily duty of crews of any size in this operation can be calculated.

TABLE XXIX.—*A normal day's work in hauling hay from windrows to barn with a hay loader, giving the average acreages reported for crews most frequently used and adjusted work factors for each crew.*

[Net hours in the field, 9.53.]

Number of men.	Number of horses.	Unloading by hand.			Unloading with sling or fork.		
		Acreage per day.	Number averaged.	Adjusted acreage.	Acreage per day.	Number averaged.	Adjusted acreage.
2	2	5.29	59	4.25	7.66	71	6.15
	4	6.50	6	5.20	6.62	8	7.30
3	2	5.86	69	5.00	7.84	88	6.70
	4	7.05	37	6.00	8.98	48	7.90
4	4	7.81	26	7.00	10.16	37	9.15
	6	7.66	6	8.00	10.37	8	10.25

In hauling hay from cocks to barn the work is done with two men by 41 per cent of farmers, 40 per cent use three men, and 19 per cent use larger crews. Only two horses are used by 73 per cent and 19 per cent use four horses. Although three-man crews are much less efficient from the standpoint of acres cleared in a day than two and four man crews, nearly as many of the former are used in this operation as are reported with two men. Arrangement of the data by length of haul showed no relation between distance to stack or barn and the amount done daily. Any time that may be lost in hauling 200 rods or less as compared with shorter distances within this limit is apparently regained through increased efficiency of the crew in other directions. The size of the load does not appear to be a factor affecting the acreage cleared in a day, since those reporting larger loads and somewhat increased acreages also used somewhat larger crews, on the average. The hay fork and sling add from 30 to 50 per cent to the efficiency of the crews in this work. It was also found that those who haul hay directly from the field with hay loaders can put away about one-third of an acre more daily per man than those who haul it from cocks, other conditions being equal. With hay loaders the operation of bunching and cocking is also eliminated.

In Table XXX the reported acreages for crews used in hauling hay from cocks to barn have been brought together, only the more common crews being presented. In deriving the adjusted acreages the original data for two men were reduced 20 per cent; those for

three men, 10 per cent; those for four men, 10 per cent; those for five men, 10 per cent for the 6-horse crews; and those for 6 men were raised 10 per cent or more. From the adjusted acreages the daily duty of any combination of men and horses can be ascertained.

TABLE XXX.—*A normal day's work in hauling hay from cocks to barn, giving the average daily acreage reported for the crews most frequently used and adjusted work factors for each crew.*

[Net hours in the field, 9.38.]

Number of men.	Number of horses.	Unloading by hand.			Unloading with sling or fork.		
		Acreage per day.	Number averaged.	Adjusted acreage.	Acreage per day.	Number averaged.	Adjusted acreage.
2	2	4.39	398	3.50	6.14	287	4.90
	4	5.30	15	4.30	7.94	17	6.10
3	2	4.55	331	3.90	6.44	315	5.50
	4	6.14	55	4.75	8.16	70	6.65
4	4	7.17	84	6.45	10.14	77	9.10
	6	9.33	3	7.25	14.25	4	10.25
5	4	7.70	22	7.70	10.70	30	10.70
	6	9.71	7	8.66	12.33	12	11.90
6	4	8.03	19	8.80	10.52	22	12.45
	6	9.11	9	9.85	11.53	15	13.60
	8	5.00	1	10.80	11.60	5	14.80

In stacking hay in the field with the aid of sweep rakes or hay buckers 32 per cent of farmers use a crew of four men and about equal numbers use three and five man crews, while only 9 per cent undertake the operation with two men. From the limited number reporting this method of making hay it appears that two, four, and six horses are equally common. Comparison of the results attained in haying with sweep rakes and without them shows an advantage in favor of this simple and inexpensive addition to the equipment of about 40 per cent, while much of the cost of raking and cocking is also eliminated. Analysis of this data also shows decreasing efficiency per man and per horse as the crews become larger

In Table XXXI the original averages for the most common crews used in stacking hay with sweep rakes are given, together with adjusted acreages for each of these crews. From this table the daily duty of crews of any size can be ascertained. In arriving at the adjusted acreages the original data for the smaller crews were reduced from 10 to 20 per cent more than that for the larger crews.

In Table XXXI the data for stacking hay in the field by hand have been brought together by the same method used for other haying tables. The reported acreages for the smaller crews have been reduced, while some of the acreages for the larger crews have been raised, in arriving at the table of adjusted factors set out in the last column.

TABLE XXXI.—*A normal day's work in stacking hay in the field, with and without sweep rakes, giving the average daily acreages reported for the crews most frequently used and adjusted acreages for each crew.*

[Net hours in the field, 9.70.]

Using sweep rakes.					Without sweep rakes (by hand).				
Number of men.	Number of horses.	Stacked per day.	Number averaged.	Adjusted acreage.	Number of men.	Number of horses.	Stacked per day.	Number averaged.	Adjusted acreage.
		Acres.					*Acres.*		
2	2	9.70	37	6.10	2	2	4.85	103	3.90
	4	13.75	4	9.20		4			5.90
3	2	9.77	48	7.80	3	2	5.38	80	5.10
	4	15.48	33	10.90		4	8.03	26	7.15
	6	14.55	11	13.80	4	2	8.30	27	6.60
4	2	11.32	31	9.40		4	9.52	82	8.90
	4	15.22	38	12.20		6	14.06	8	11.20
	6	18.75	47	15.00	5	2	9.00	11	7.40
5	4	12.80	19	12.90		4	9.37	46	9.60
	6	19.70	42	15.80		6	12.50	10	11.90
	8	23.50	8	18.60	6	4	7.50	12	11.20
6	6	24.66	6	18.20		6	12.20	12	13.00
	8	20.33	15	20.40		8	10.00	2	14.80

Of those farmers who stack hay in the field by hand, about equal numbers use two, three, and four men in the crew, five and six men being comparatively rare. In 49 per cent of cases, two horses are used, 36 per cent use four horses, and 8 per cent use six horses. Odd numbers of horses are seldom reported and add nothing to the efficiency of the crew.

BALING HAY.

In baling hay with the horsepower type of press it appears that 34 per cent of crews consist of four men, while about 25 per cent consist of three men and an equal proportion of five men. In 75 per cent of the instances reported two horses are used. The capacity of balers is much greater than the demands made upon them by the average crew of four men or less. The 2-horse type has somewhat greater capacity than the 1-horse baler. The daily duty per man is about 2.25 tons with the sweep type, and with the gasoline-engine-driven type, which averages a larger press, the daily duty is 2.75 tons.

In Table XXXII the original averages for each size of crew under the 1-horse and 2-horse types are given, together with adjusted tonnages based on the average tons per man for each type. In the same table limited data are also given for baling with a gasoline engine for power arranged according to the number of men in the crew. The six-man crew is the most common and crews larger than eight men are not frequently found practicable. Within limits of four to eight men the output of balers is in proportion to the available men to bring the hay to the hopper. A 10 or 12 horsepower engine is most generally used in this operation, smaller engines than this being generally overloaded in this work.

TABLE XXXII.—*A normal day's work in baling hay from the stack or barn with sweep power and with an engine, giving the average number of tons baled daily as reported for the crews commonly used, with adjusted factors for each crew.*

[Net hours at work, 10.10.]

USING HORSEPOWER.

Type of baler.	Number of men.	Baled per day.	Number averaged.	Factor for each crew per day.
		Tons.		*Tons.*
1-horse sweep	2	3.6	4	4.8
	3	7.2	35	7.2
	4	9.1	17	9.6
	5	12.5	2	11.9
2-horse sweep	2	10.0	1	5.1
	3	8.6	75	7.4
	4	9.6	123	9.6
	5	10.7	95	11.9
	6	10.9	26	14.1
	7	15.5	11	16.4
	8	15.5	2	18.6

USING GASOLINE ENGINE.

Number of men.	Horse-power of engine.	Baled per day.	Number avereged.	Factor for each crew per day.
		Tons.		*Tons.*
3	5.44	13.56	16	7.7
4	6.28	10.63	31	10.5
5	8.29	13.20	39	13.4
6	10.41	16.26	44	16.3
7	12.09	20.17	32	19.1
8	12.53	20.29	31	21.9
9	16	26.66	6	24.8
10	11.90	27.50	10	27.6
11	14	31.25	4	30.5

HARVESTING GRAIN.

The grain binder is an implement of comparatively light draft in proportion to its width of cut. With this machine the efficiency per horse increases as the width of cut is increased, as does also the acreage per foot in width. Since the draft of the binder is due principally to the propelling of the gearing mechanism, increases in the width of cut up to 8 or 10 feet add little to the load on the horses except the side draft. The daily duty per foot of cut is about 2 acres and that per horse is about 4 acres. With the grain header the daily duty per foot in width is about 2.35 acres, and the duty per horse about 5.5 acres.

With a combined header and thrasher meager data indicate that a fair day's work is from 22 to 28 acres, depending upon the width of cut, which usually ranges from 10 to 14 feet.

In Table XXXIII the original averages for those widths of binder and header most frequently used are given, together with adjusted

acreages and allowances for other numbers of horses. From this table the daily duty of grain-harvesting equipment can be readily determined for any width and practical unit of horsepower.

TABLE XXXIII.—*A normal day's work in harvesting grain with a binder and header, giving the average acreages reported for widths most frequently used, adjusted factors for those widths, and scale of allowances for other teams.*

[Net hours in the field, 10.33.]

Implement.	Width of implement.	Number of horses generally used.	Harvested per day.	Number averaged.	Adjusted acreage.	Other teams reported.	Allowance for each other horse.
	Feet.		*Acres.*				*Acres.*
Grain binder	5	3	9.26	91	8.35	2,4	1.50
	6	3	10.96	782	9.90	2,4,5	1.70
	7	4	15.24	329	13.80	3,5,6	1.90
	8	4	18.19	354	17.25	3,5,6	2.10
Grain header	10	6	24.18	11	23.70	4,5,6	1.30
	12	6	28.56	107	25.70	4,5,6,8	1.35
	14	6	28.46	13	26.40	8	1.40

The data for setting up grain in shocks after the grain binder are given in Table XXXIV in terms of one man according to the yield per acre. Through inadvertence the inquiry did not specify the kind of grain affected, so that the data of the table must be taken as a composite for oats, barley, and wheat, and is probably most accurate if the crop is assumed to be oats.

TABLE XXXIV.—*A normal day's work in shocking grain by one man, giving the average daily acreage according to the yield per acre.*

[Net hours in the field, 9.91.]

Yield per acre.	Shocked per day.	Number averaged.
	Acres.	
1 to 20 bushels	10.09	766
21 to 40 bushels	8.73	698
41 to 60 bushels	8.46	164
61 bushels and over	7.36	22

The averages for crew work in stacking grain from the shock are arranged in Table XXXV by crews most frequently used. In general, the daily duty per man is from 2.75 to 3.5 acres in stacking in the field, and from 2.5 to 3 acres when hauling to the barn. From the table of adjusted acreages in columns 5 and 8 the daily duty of any crew in work of this character can be approximated. In those regions where stacking grain is practiced, crews of more than four men are not common.

TABLE XXXV.—*A normal day's work in stacking grain from the shock, giving the average daily acreage reported for crews most frequently used and adjusted factors for each crew.*

Number of men.	Number of horses.	Stacking in the field.			Stacking at the farmstead.		
		Stacked per day.	Number averaged.	Adjusted acreage.	Stacked per day.	Number averaged.	Adjusted acreage.
		Acres.			*Acres.*		
2	2	8.02	226	6.40	6.69	189	5.30
	4	10.64	7	9.30	7.16	3	8.90
3	2	8.32	72	6.70	7.22	64	5.80
	4	14.35	132	9.60	11.45	92	8.40
4	4	13.72	222	12.30	11.09	167	10.00
	6	23.25	4	15.60	19.75	4	13.00
5	4	14.05	53	12.60	12.23	44	11.00
	6	19.00	6	15.90	15.20	5	14.00
6	4	14.00	10	15.00	12.12	8	13.00
	6	18.00	7	18.20	18.20	5	16.00
	8	.....	.....	21.50	.....	.....	18.90

HARVESTING CORN.

The reports for harvesting corn with a binder have been brought together in Table XXXVI according to the number of horses used with the harvester and by yields under each number of horses. With one exception the data show a decreasing acreage with increasing yield in all three groups. This decrease is less pronounced as horses are added, indicating a considerable overload for two horses with this implement. A reasonable figure for the duty per horse in this operation is from 2 to 2.5 acres per day.

TABLE XXXVI.—*A normal day's work in harvesting corn with a binder, giving the average acreages reported according to the number of horses for designated yields.*

Number of horses.	Yield per acre.	Harvested per day.	Number averaged.
		Acres.	
2	1 to 40 bushels	7.47	52
	41 to 60 bushels	6.70	59
	61 bushels and over	5.57	49
3	1 to 40 bushels	7.63	225
	41 to 60 bushels	7.16	179
	61 bushels and over	6.30	68
4	1 to 40 bushels	8.16	54
	41 to 60 bushels	8.27	60
	61 bushels and over	7.21	14

In Table XXXVII the harvesting of corn with a platform cutter is arranged according to the number of men in the crew. The platform cutter cuts two rows at a time, and its capacity is determined largely by the number of men available to tie and set up the corn as it is cut. The average acreage per man is 2.93 and the average acreage per horse 4.17 acres. In this table the adjusted acreages have been computed by decreasing the reported averages for two men and increasing those for three and four men.

TABLE XXXVII.—*A normal day's work in harvesting corn with a platform cutter, giving the average daily acreages reported for crews commonly used and adjusted factors for each crew.*

Number of men.	Number of horses.	Harvested per day.	Number averaged.	Adjusted acreage.
		Acres.		
2	1	5.08	118	4.60
	2	5.80	35	5.20
3	1	5.70	10	5.90
	2	4.50	4	6.80
4	2	8.00	24	8.20
	4	9.00	2	10.00

In Table XXXVIII the reported averages for cutting, shocking, and tying corn by hand, using the ordinary corn knife, have been brought together by yield per acre. Increases in the yield add to the bulk of the stalks to be handled and reduce the acreage cut daily. From 1.4 to 1.7 acres daily can be harvested by one man in this manner. The operation of tying and shocking corn after the corn binder is also reported in the table in the same way. The daily duty of a man at this work is from 3 to 5 acres, depending upon the yield.

TABLE XXXVIII.—*A normal day's handwork in harvesting corn, giving the average daily acreages for one man according to the yield per acre.*

Operation.	Yield per acre.	Harvested per day.	Number averaged.
		Acres.	
Cutting, shocking, and tying corn by hand	1 to 40 bushels	1.65	141
	41 to 60 bushels	1.50	143
	61 bushels and over	1.40	72
Tying and shocking corn after binder	1 to 40 bushels	4.65	300
	41 to 60 bushels	3.71	268
	61 bushels and over	3.15	111

In Table XXXIX husking corn from shock is reported by those farmers who practice this method of handling the crop. The daily duty is from 42 to 55 bushels, depending upon the yield. Where corn is husked continuously from standing stalks, about 60 per cent more can be husked than when the work is done with corn in the shock, the reported daily duty being from 75 to 90 bushels per acre. Where one man husks, hauls, and unloads from standing stalks it is seen that corn can be husked about 25 per cent more rapidly than can be done from shocks into piles on the ground. The daily duty of a man husking, hauling, and unloading is reported as ranging from 50 to 70 bushels, depending upon the yield. In the table the adjusted factors have been derived by reducing the reported acreages from 10 to 20 per cent.

TABLE XXXIX.—*A normal day's work in husking corn, by one man, giving the average daily work factors, in bushels of ears, according to the yield per acre.*

[Net hours at work, 9.58.]

Operation.	Yield per acre.	Husked per day.	Number averaged.	Adjusted factor per day.
		Bushels.		*Bushels.*
Husking from shock	1 to 40 bushels	42.67	222	35
	41 to 60 bushels	45.92	336	42
	61 bushels and over	54.48	220	50
Husking from standing stalks continuously	1 to 40 bushels	76.2	224	60
	41 to 60 bushels	85.97	318	70
	61 bushels and over	87.14	147	75
Husking, hauling, and unloading, from standing stalks.	1 to 40 bushels	50.26	388	45
	41 to 60 bushels	68.05	450	55
	61 bushels and over	69.73	131	62

HARVESTING POTATOES.

In Table XL harvesting potatoes with plows and diggers is grouped by the method employed and number of horses used. The reported acreages have been reduced 10 per cent in arriving at the adjusted acreage in the last column of the table. For plowing out Irish potatoes with an ordinary plow, about equal numbers, out of the 108 which were averaged, reported 1, 2, 3, and 4 acres. Potato rows are often planted in every other furrow of the ordinary 12 or 14 inch plow, and the work of plowing them out is done more carefully than simple field plowing. Twice the daily duty of a 2-horse walking plow being about 3.70, the allowance for the care required in the plowing of potatoes should reduce this acreage toward that given in the average, indicating that the factor 2.40 is substantially correct. In digging Irish potatoes with an elevator digger a 3-horse team is not often used, but the 4-horse team is almost as general as two horses. The acreage increases with increase of power, each additional horse adding about 20 per cent to the amount done daily. A digger drawn by two horses appears to be 40 per cent more efficient from the standpoint of acreage covered in a day than the ordinary 2-horse plow, but two horses are probably much overloaded by this implement. Meager data on digging sweet potatoes with a sweet-potato plow are also included in the table. Since sweet potatoes are planted in rows as much as twice the distance apart given to Irish potatoes, it is apparent from comparing these data with that for plowing out Irish potatoes that the deeper and wider furrow should result in an acreage for this operation about equal to the average of 3.60 reported in the table.

TABLE XL.—*A normal day's work in digging potatoes, giving the average acreages reported.*

[Net hours at work, 9.58.]

Operation.	Number of horses.	Dug per day.	Number averaged.	Adjusted acreage.
		Acres.		
Digging sweet potatoes with sweet-potato plow	2	4.02	38	3.60
Digging Irish potatoes with ordinary plow	2	2.73	108	2.40
Digging Irish potatoes with potato digger	2	3.84	164	3.45
	3	4.06	25	3.70
	4	5.21	129	4.70

The quantity of Irish potatoes that can be picked up after plowing out with an ordinary plow and elevator digger is shown in Table XLI in terms of yield per acre. The amount that can be dug with a fork and picked up is also given in the same table. Where the yields are the same, it is seen that 40 per cent more can be picked up after an elevator digger than can be gathered after an ordinary plow. It appears also that twice as much human labor is required to dig and pick up a bushel of potatoes by hand as is required to pick up after an elevator digger.

TABLE XLI.—*A normal day's work in picking up Irish potatoes, giving the average number of bushels per day per man by designated yields.*

[Net hours in the field, 9.58.]

Operation.	Yield	Picked up per day.	Number averaged.
		Bushels.	
Picking up after ordinary plow	75 bushels	59.31	475
	125 bushels	76.04	458
	200 bushels and over	95.21	442
Picking up after elevator digger	75 bushels	82.03	211
	125 bushels	103.76	218
Digging and picking up by hand	1 to 125 bushels	32.31	285
	126 to 200 bushels	42.67	290
	200 bushels and over	46.35	51

Averages for the operation of hauling potatoes from the field and unloading into the cellar are given in Table XLII by bushels in the load in terms of bushels in a day. The larger loads are the most economical from the standpoint of work accomplished daily. Arrangement of this data by distance hauled showed no relation between the distance and amount of work done daily.

TABLE XLII.—*A normal day's work in hauling potatoes from field to cellar, giving the average daily factors in bushels according to the size of load.*

[Net hours at work, 9.58.]

Size of load.	Hauled per day per man and team.	Number averaged.
	Bushels.	
1 to 30 bushels	194.16	55
40 bushels	223.35	73
50 bushels	276.46	120
60 bushels	353.71	35
65 to 75 bushels	459.87	16

THRASHING OPERATIONS.

In Table XLIII the original data for those thrashing crews most frequently reported are tabulated by thrashing from shock and by thrashing from stack or barn, the averages being given for each crop. Taking the reported output for each crew and crop as standards, there is included in the table a scale of allowances for each departure of one man and for each difference in yield of 1 bushel, together with the range in the number of men found by experience to be reasonably adequate in each case. From analytical tables it was found that increases in the crew were not attended with proportional increases in the daily output of thrashed grain. In calculating the duty for any crew other than those in the table it is therefore advisable to reduce the result obtained for the larger crews from 5 to 10 per cent and to increase the results computed for smaller crews in like proportion.

In thrashing from stack or barn more than four horses are rarely found necessary. In thrashing from the shock a horse for each man is the rule. The length of cylinder used ranges from 18 to 44 inches, the 36-inch length being in most general use, with the 32 inch second in favor. Increased capacity is attended by increased output daily when accompanied by adequate crews, the capacity of the larger machines when properly fed being considerably in excess of the ability of the average crew to deliver the grain to the machine. Much larger crews are used in shock thrashing, but the amount done per day and per man is about the same for crews of the same size. The larger crews used in shock thrashing give larger quantities per day, but the output per man and per horse decreases with increased crew, thus adding to the thrashing cost per bushel. The thrashing charge against clover and alfalfa is about 4 to 5 times that for timothy, 15 to 20 times that for flax, 20 to 25 times that for wheat, and 30 to 40 times that for oats.

TABLE XLIII.—*A normal day's work in thrashing grain, giving the daily averages in bushels per day for crews most frequently used, with adjustments for different crews and yields.*

[Net hours at work, 9.6.]

Method used and crop.	Men in crew.	Yield per acre.	Thrashed per day.	Number averaged.	Allowance per day for each difference of—		Other feasible crews (number of men).
					One man in crew.	One bushel in yield.	
From stack or barn:		*Bushels.*	*Bushels.*		*Bushels.*	*Bushels.*	
Wheat	12	22	1,050	166	87	20	8–14
Oats	12	40	1,802	153	150	25	8–14
Flax	10	11	690	26	69	10	6–12
Alfalfa, clover	10	4	50	66	5	4	8–14
Timothy	13	7	262	42	21	6	10–16
From shock:							
Wheat	20	23	1,349	121	67	20	10–24
Oats	20	40	2,358	104	117	25	10–24
Flax	16	13	837	20	52	10	8–20
Alfalfa, clover	9	3.5	55	85	6	4	6–14
Timothy	12	6.5	200	56	17	5	10–16

MISCELLANEOUS WORK.

In Table XLIV the average data for picking apples and strawberries, for scooping grain, and for milking cows are tabulated. The duty of one man in picking apples ranges from 34 bushels where the trees yield less than 10 bushels each to 45 bushels where the yield per tree is over 10 bushels. The reports for picking strawberries ranged from 50 to 200 quarts, a wide variation explained by the equally wide variation in yields at different seasons and at different pickings in the same season, also by the practice of paying by the quart, so that growers are not put to the necessity of knowing how much the laborer earns at such work. At the average rate reported for scooping grain it would be necessary to handle $1\frac{1}{3}$ bushels or about 6 to 8 scoopfuls each minute, a rate that can be greatly exceeded, if necessary, in intermittent work of this character. While the average for 1,014 reports on milking cows can doubtless be taken as reasonably conclusive, for practical purposes a reduction of 10 per cent, placing the hourly duty for this operation at 7 cows per hour, should be found more acceptable.

TABLE XLIV.—*A normal day's work in miscellaneous operations, giving the average work factors in terms of designated units per man per day or hour.*

Operation.	Net hours at work.	Conditions.	Work factors.		Number averaged.
			Daily.	Hourly.	
Picking apples	9.58	1 to 10 bushels per tree	33.96 bushels		221
		Over 10 bushels per tree	44.84 bushels		161
Picking strawberries	9.48	At average yields	99.71 quarts		105
Scooping grain		From bin or box		2.47 tons	480
Milking cows		Cows per hour		7.94	1,014

HAULING FARM PRODUCE TO MARKET.

In Table XLV data on the operation of loading, hauling to market, and unloading certain farm commodities have been assembled by distance to market and expressed in loads per day for each distance. Inspection of the averages for each product shows a fairly uniform decrease with increasing distance, with the exception of 8 instances out of 100, these exceptions being in cases where very few reports were made. The average for all commodities shows no irregularities. The number of loads hauled daily is seen to vary with the time taken to load and unload or with the nature of the product or manner of handling it. From the limited number who reported for distances greater than 10 miles it appears that smaller loads are hauled for this than for the shorter distances, doubtless on account of poorer roads and greater grades in the more remote localities. The average

weight of loads ranged from 2,267 to 2,843 pounds. The average distance from market of some 3,000 farmers furnishing these data is 4.4 miles. Inspection of Table XLV shows differences in cost of marketing the different commodities ranging as high as 50 per cent.

TABLE XLV.—*A normal day's work in hauling to market with wagon for one man and two horses (loading, hauling, and unloading), giving the number of loads per day, by distance hauled, for each commodity.*

Distance hauled, etc.	Baled cotton.	Corn from crib.	Barrels.	Bags.	Baled hay.	Small grain from bin.	Cabbage.	Loose cotton.	Potatoes from cellar.	Loose hay.	All commodities.	Number averaged.
1 mile	6.57	5.00	4.57	5.29	5.25	4.51	3.87	2.50	3.17	3.64	4.39	204
2 miles	3.86	3.75	3.89	3.91	3.92	3.37	3.27	2.53	3.02	2.69	3.43	734
3 miles	3.63	2.95	3.20	3.23	3.05	2.93	2.58	2.50	2.29	2.19	2.79	859
4 miles	2.62	2.47	2.80	2.64	2.51	2.52	2.34	2.09	2.06	1.99	2.37	724
5 miles	2.29	2.15	2.11	2.11	2.19	2.14	1.89	1.81	1.78	1.72	2.02	802
6 miles	2.55	1.99	2.06	2.04	2.03	1.99	1.80	2.00	1.66	1.82	1.94	467
7 miles	2.33	1.79	1.57	1.87	1.87	1.71	1.70	2.50	1.46	1.48	1.72	130
8 miles	1.66	1.31	1.12	1.27	1.44	1.40	1.15	1.14	1.22	1.22	1.30	177
9 miles	1.00	1.18	1.33	1.25	1.50	1.42	1.25	1.00	1.10	1.30	1.26	74
10 miles	1.33	1.17	1.09	1.19	1.10	1.16	1.00	1.21	1.10	1.09	1.14	231
Number averaged	114	767	204	294	688	735	271	114	532	683	4,402	.....
Average number of loads, 1 to 10 miles	2.86	2.69	2.66	2.67	2.75	2.56	2.28	2.00	2.09	2.07	2.51	.....
Average number of miles	4.9	4.2	4.5	4.4	4.2	4.34	4.4	4.8	4.4	4.3	4.37	.....

While there are wide differences in the cost per load for loading, hauling to market, and unloading the various farm products, inspection of the averages for all commodities suggests certain relationships between the length of haul and the number of loads that can be transported daily. These relationships are indicated in Table XLVI. Under line *a* the length of haul is given, and below these distances in line *b* is recorded the number reporting for each distance, while in line *c* the average loads reported for each distance is given. In lines *d* and *e* are given loads per day computed for each distance as follows: The distances computed in line *d* are based on the number of loads reported for 3 miles (2.79), since a greater number (859) haul that distance than any other. The distances in line *e* are based on the reported number of loads for 5 miles (2.02), since the second largest number (802) report for that distance. In both *d* and *e* the computed loads for the other distances from 1 to 10 miles are found by solving inverse proportions between the basic number of loads and the square root of the respective distances to market. Inspection of the results so obtained as compared with the original averages for all commodities in line *c* indicates that, within a radius of 8 miles from market where transportation is effected with horses and wagons, the marketing advantage that one farm has over another may be considered to be inversely proportional to the square root of the length of haul.

TABLE XLVI.—*A normal day's work in marketing, giving the average number of loads hauled daily for all commodities for each distance from 1 to 10 miles and the relation of distance to market to the number of loads that can be loaded, hauled to market, and unloaded.*

Character of data.	*a*. Distance to market (miles).									
	1	2	3	4	5	6	7	8	9	10
b. Number reporting	204	734	859	724	802	467	130	177	74	231
c. Average number of loads at each distance	4.39	3.43	2.79	2.37	2.02	1.94	1.72	1.30	1.26	1.14
Number of loads based on—										
(*d*) 3-mile average	4.82	3.32	2.79	2.41	2.16	1.98	1.82	1.70	1.60	1.54
(*e*) 5-mile average	4.50	3.19	2.60	2.25	2.02	1.84	1.61	1.59	1.50	1.42

SUMMARY.

(1) Daily and seasonal working factors for farm labor and equipment are of primary importance in farm organization and management.

(2) The seasonal and daily duty of men and equipment for an agricultural area can be reliably approximated by averaging many estimates for each operation made by farmers in the region. Figures so obtained are as accurate for practical purposes as those secured by more refined methods.

(3) Data secured in this manner will yield dependable averages in proportion to the experience of those giving the original data and to the care with which the estimates are made. They are, then, not guesses, but the concrete expression of seasoned judgment.

(4) Those engaged in farming have quite definite conceptions of the duty for the simpler operations where but one or two men and one or two teams are involved.

(5) Where many men and units of equipment are used in an operation there is less definite conception of what constitutes a fair day's work, since fewer have had experience with the larger crews, and the range of variation is greater. More data are therefore necessary to insure useful averages.

(6) With implements of heavy draft and also with many of the lighter implements, the increase in dimensions is not attended with proportional increases in work accomplished. For this reason the widths, sizes, and crews most frequently used are taken as affording the most reliable standards, the duty of variations from these being calculated by the use of factors included in the tables.

(7) The increase in the number of men in the crew and in the complexity of the operation are attended by lost motion and decrease in efficiency per unit of labor and equipment. The simpler operations are the most economical from the standpoint of work done daily.

(8) Since certain sizes and units of equipment are used by the majority of farmers, it would be impossible by any method to secure sufficient original data for the less common sizes and crews to yield averages of value. In the tables, therefore, factors have been deduced for some of the less common units of equipment. These deduced factors are based on an analysis of general tabulations for each operation. For practical reference purposes the tables are thus made complete.

(9) In arriving at work standards by the method here used it is believed that certain biased influences operate to produce averages somewhat above normal. In many of the tables, therefore, compensation has been made for the bias by reducing the adjusted factors from 5 to 20 per cent below the original averages.

(10) The daily duty for nearly all of the major operations in American agriculture can be ascertained from the tables in this bulletin. These work factors represent the average of conditions in the United States and can not be too strictly applied to every climate, topography, or soil.

(11) For convenient reference, averages of the data relating to field implements referred to in the text have been summarized in Table XLVII.

TABLE XLVII.—*Summary of work factors for operations with field implements.*

Operation or implement.	Power unit (number of horses).	Daily duty per foot of width.	Range of reported widths.	Most usual width per horse.
		Acres.		*Feet.*
Walking plow	2	1.62	8 to 14 inches	0.50
	3	2.00	10 to 16 inches	.44
Sulky plow	2	1.61	10 to 16 inches	.58
	3	2.13	12 to 16 inches	.44
	4	2.23	14 to 18 inches	.33
Gang plow	4	2.08	18 to 28 inches	.58
	5	2.21	24 to 28 inches	.47
	6	2.20	24 to 32 inches	.39
Traction engine gang	15 to 60 horsepower.	2.00	4 to 30 feet	.33
Spike-tooth harrow:				
On fresh plowing	2	1.40	6 to 12 feet	4.00
On well-packed land		1.60		
On fresh plowing	3	1.50	8 to 16 feet	3.50
On well-packed land		1.80		
On fresh plowing	4	1.70	10 to 26 feet	4.25
On well-packed land		2.00		
Spring-tooth harrow:				
On fresh plowing	2	1.20	4 to 8 feet	3.00
On well-packed land		1.40		
On fresh plowing	3	1.30	5 to 10 feet	2.33
On well-packed land		1.60		
On fresh plowing	4	1.50	6 to 12 feet	2.00
On well-packed land		1.70		
Disk harrow:				
On fresh plowing	2	1.10	4 to 8 feet	3.00
On well-packed land		1.20		
On fresh plowing	3	1.20	6 to 10 feet	2.25
On well-packed land		1.50		
On fresh plowing	4	1.60	6 to 10 feet	2.00
On well-packed land		1.90		
Land roller	2	1.60	5 to 12 feet	4.00
	3	1.65	5 to 12 feet	2.00
	4	1.75	8 to 16 feet	2.50

TABLE XLVII.—*Summary of work factors for operations with field implements*—Con.

Operation or implement.	Power unit (number of horses).	Daily duty per foot of width.	Range of reported widths.	Most usual width per horse.
		Acres.		*Feet.*
Grain drill	2	1.40	4 to 8 feet	3.25
	3	1.50	6 to 10 feet	2.50
	4	1.75	6 to 12 feet	2.25
	6	1.90	8 to 12 feet	1.75
Corn or cotton planter:				
1-row	1	2.20	36 to 48 inches between rows	3.00
Do	2	3.00		1.50
2-row	2	3.75		1.50
Covering seed potatoes	1	2.00	24 to 32 inches between rows	2.00
	2	2.50		2.33
Marking planting rows	1	1.50	3 to 12 feet	3.00
	2	2.00		6.00
Potato planter:				
1-man	2	2.35	24 to 32 inches between rows	2.33
2-man		2.10		2.33
Lime spreader	2	1.10	6 to 12 feet	4.00
Fertilizer drill	2	1.30	5 to 10 feet	3.00
	3	1.40	6 to 12 feet	2.66
Field sprayer	1	1.10	3 to 4 rows each trip	11.00
	2	1.25		6.00
Mowing hay	2	1.60	4 to 7 feet	2.50
Raking hay	1	1.50	6 to 12 feet	9.00
	2	1.60	8 to 16 feet	6.00
Tedding hay	1	1.40	6 to 8 feet	7.00
	2	1.70	6 to 10 feet	4.25
Grain binder	3	1.85	4 to 7 feet	2.00
	4	2.15	5 to 8 feet	2.00
	5	2.25	5 to 8 feet	1.66
Grain header	4	2.10	10 to 12 feet	3.00
	5	2.20	10 to 12 feet	2.25
	6	2.30	12 to 14 feet	2.33
Corn binder	3	2.00	Rows 36 to 48 inches (average yields)	1.50
Cultivating	1	4.25		
	2	6.75		
Knapsack sprayer		1.00		
Wheelbarrow seed sower		1.40	10 to 16 feet	
Hand corn planter		1.30	36 to 48 inches between rows	

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 4

Contribution from the Forest Service, Henry S. Graves, Forester.
In cooperation with the Bureau of Plant Industry, W. A. Taylor, Chief.
October 27, 1913.

THE RESEEDING OF DEPLETED GRAZING LANDS TO CULTIVATED FORAGE PLANTS.

By Arthur W. Sampson,
Plant Ecologist.

(With prefatory note by Frederick V. Coville, Botanist, in Charge of Economic and Systematic Botany, Bureau of Plant Industry.)

PREFATORY NOTE.

In the investigations planned in 1907 for the improvement of overgrazed lands on the National Forests provision was made for experiments in the artificial seeding of areas in which the natural vegetation had been destroyed or had become relatively unproductive.

In the year 1902 experiments in the reseeding of mountain meadows had been begun by Mr. J. S. Cotton, of the Bureau of Plant Industry. A report on these experiments was published in 1908 as Bulletin 127 of the Bureau of Plant Industry, under the title "The Improvement of Mountain Meadows." The conclusions were that the artificial reseeding of these moist areas was practicable and that timothy and redtop were the most promising grasses for such situations. Continued observation of the original plots, by Mr. Cotton, up to the year 1911, confirmed and extended the earlier conclusions.

The reseeding experiments with cultivated forage plants, begun by the Forest Service in 1907 in cooperation with the Bureau of Plant Industry, are over 500 in number and were located in many kinds of situations. The results are consequently of value as showing not only that reseeding is practicable and profitable but especially as showing in detail to what conditions of soil and moisture it is applicable, under what conditions reseeding is bound to fail, what grasses and clovers have been successful and are best suited to particular situations, the best time of year and the best methods of sowing the seed to secure a good stand, and the extent to which the seeded areas must be protected from stock before the young plants can withstand grazing and trampling.

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The percentage of National Forest lands suited to seeding with cultivated grasses is small, but the total area is sufficiently large to make such seeding an important means of increasing the grazing resources of the Forests and to warrant the systematic adoption of the practice of seeding for all the areas to which it is adapted.—FREDRICK V. COVILLE.

THE RANGE PROBLEM.

As anyone familiar with the West knows, unregulated use of the open range has produced a marked deterioration in the forage crop. The most obvious method of providing for range improvement is to close overgrazed areas against stock until the range has regained a normal condition through natural revegetation. This, however, means both a very serious interference with the stockmen who are deprived of use of the range and the waste of the forage which grows during the time that the range is closed. Moreover, in many cases such changes have been produced in the range that betterment takes place very slowly. The most valuable forage plants have either been almost eliminated or had the balance so turned against them and in favor of less desirable plant growth that they can not readily recover the ground they have lost.

The grazing problem is the problem of getting the largest possible use out of the range. This means making the range grow the best possible crop of forage, taking into consideration quality as well as quantity, while making this crop available at the times when the stockman needs it. Evidently the problem has two sides. One side is the study of forage production. The other side is the devising of methods of regulating use of the range by stock so as to utilize the largest possible amount of the forage produced with the least possible reduction of the power to grow forage while conforming to the practical requirements of the stock industry.

In dealing with depleted ranges the first necessity is to learn how the reestablishment of a growth of valuable forage plants can be brought about. Two possibilities are open. The first is that of securing revegetation through natural reseeding. The second is that of replenishing the growing stock through the establishment of a growth of cultivated or introduced forage plants.

INVESTIGATIONS OF THE NATIONAL FOREST RANGE PROBLEM BY THE FOREST SERVICE.

On the National Forests the amount of grazing has been regulated with careful consideration for the condition of the range. Very badly overgrazed areas have in some cases been entirely closed to use. Where conditions are less serious the allotments of stock have been cut down to the point deemed necessary in order to permit the

range to recover. Under this system marked improvement in the carrying capacity has taken place. Nevertheless, there is evident need for bringing about improvement more rapidly.

This need has led the Forest Service to undertake, in cooperation with the Bureau of Plant Industry of the Department of Agriculture, a series of grazing studies dealing with the various phases of the whole range problem. Publications setting forth some of the results of these studies have already been issued.[1] One line of experiments has studied the methods of handling stock, with reference especially to the value of inclosed pastures as a means of preventing waste of forage through trampling, of lessening losses, of increasing the number of stock which can be grazed on a given area, and of improving the condition of the range. Another line of studies has sought information concerning the various species of range plants, their forage value, the conditions necessary for their growth and spread, and the nature of the interference produced by grazing use—in other words, the things which must be known in order to understand why and how grazing has reduced the supply of forage and how range regeneration may best be brought about. The third line of studies has consisted in experiments to ascertain to what extent range improvement can be brought about through artificial sowing.

It is a matter of common knowledge that much of the seriously overgrazed range, such as mountain meadows and well-drained parks, have exceedingly fertile soils and originally produced a large native forage crop of high quality, but now support few or no valuable range plants. It is evident that natural revegetation can not be brought about where the original vegetation has been completely destroyed and the land left in a denuded condition. If such land is to be restocked within a reasonable length of time, seed from forage plants adapted to the local conditions must be introduced.

These seriously overgrazed lands differ so widely in soil and growth conditions that before doing any great amount of seeding it was necessary to obtain in much detail, through carefully planned experiments, information concerning the natural factors which limit the successful application of artificial reseeding, the adaptability of various species of plants to the various sets of conditions, the methods which will procure the best results, and the question of cost and returns—in other words, to find out where artificial revegetation can be brought about, what are the most effective means, and whether they will pay.

[1] The following are the titles of these publications: Jardine, James T., The Pasturage System for Handling Range Sheep, Circ. 178, U. S. Forest Service, 1909. Sampson, Arthur W., The Revegetation of Overgrazed Range Areas, Circ. 158, U. S. Forest Service, 1908. Sampson, Arthur W., Natural Revegetation of Depleted Mountain Grazing Lands, Circ. 169, U. S. Forest Service, 1909.

Both extensive and detailed studies have been carried on during the past five years. As a result it is now possible to give some definite information concerning (1) where reseeding may profitably be undertaken as shown, for example, by the soil and the character of the native vegetation; (2) what species to use; (3) when to sow; and (4) what soil treatment should be applied under the various conditions.

LOCATION AND CHARACTER OF THE REVEGETATION STUDIES.

Since the National Forests extend from the Canadian to the Mexican line and embrace all the important gradations of climate, altitude, moisture, and soil conditions, the investigations were extended over as wide a territory as possible. The location of the experiments is shown in figure 1.

FIG. 1.—Location of the reseeding projects on grazing areas within the National Forests. The star indicates the area where the most intensive study was made.

It will be seen that experimental reseeding has been undertaken in 11 States. Eighty-six important grazing forests out of the 163 National Forests were included in the study, and more than 500 individual experiments were established.

To supplement these extensive experiments conducted by local forest officers, a series of detailed studies was carried out by the writer on the Wallowa National Forest, in northeastern Oregon. These intensive studies were begun in 1907, and were made upon small plots of varying local conditions. Special attention was given to determining the exact causes of failure or success of seeding through careful observations of the potent factors (especially the temperature and soil-moisture conditions during the main growing season) likely to influence the results.

THE GENERAL STUDIES.

These were initiated in 1909 and continued in 1910 and 1911. The tests were confined to plots averaging 4 acres, selected as representative of general conditions. Progress reports on the experiments were submitted at the close of each growing season.

SPECIES SOWN.

The following 14 grasses and 8 species other than grasses were tried in the experiments:

GRASSES.

1. Broom grass (*Andropogon* sp.).
2. Canada blue grass (*Poa compressa*).
3. Slender wheat grass (*Agropyron tenerum*).
4. Blue grama grass (*Bouteloua oligostachya*).
5. Hard fescue (*Festuca duriuscula*).
6. Italian rye grass (*Lolium italicum*).
7. Kentucky blue grass (*Poa pratensis*).
8. Mesquite (*Hilaria cenchroides*).
9. Orchard grass (*Dactylis glomerata*).
10. Perennial rye grass (*Lolium perenne*).
11. Redtop (*Agrostis alba*).
12. Smooth or Hungarian brome (*Broms inermis*).
13. Tall meadow oat grass (*Arrhenatherum elatius*).
14. Timothy (*Phleum pratense*).

NONGRASSES.

1. Alfalfa (*Medicago sativa*).
2. Alfilaria (*Erodium cicutarium*).
3. Alsike clover (*Trifolium hybridum*).
4. Australian saltbush (*Atriplex semibaccata*).
5. Bur clover (*Medicago denticulata*).
6. Japanese clover (*Lespedeza striata*).
7. Red clover (*Trifolium pratense*).
8. White clover (*Trifolium repens*).

In the above list the 10 species most frequently employed in 449 experiments, either sown singly or in mixtures, as reported in the year 1911, were as follows:

	Projects.		Projects.
Timothy	179	Alsike clover	40
Smooth brome grass	96	Australian saltbush	19
Kentucky blue grass	84	Red clover	19
Redtop	81	Canada blue grass	20
Orchard grass	49	Italian rye grass	15

CULTURAL METHODS.

Owing to the difficulty of transportation in many localities, and to the expense involved, the seed was sown broadcast and the soil treatment resorted to in most cases consisted of inexpensive methods

which did not require agricultural implements, the use of which often results in serious erosion. In some cases wooden or brush harrows made on the ground were used. In other cases sheep driven in a compact body over the lands after sowing served the purpose of harrowing the seed into the ground.

CHARACTER OF THE LANDS.

The plots were located where the need for range improvement is greatest. The areas seeded vary in altitude from 2,000 to 10,000 feet. This range in elevation was accompanied by a corresponding diversity in the growth conditions and in the character of the native vegetation.

Among the more common and characteristic trees of the higher elevations where studies were carried on may be mentioned: Whitebark pine, foxtail pine, limber pine, subalpine fir, Engelmann spruce, and mountain hemlock. The climatic conditions characteristic of regions in which these trees predominate will be designated by the use of the term "whitebark pine zone." Some of the characteristic trees of the lower seeding stations are: Lodgepole pine, western yellow pine, sugar pine, digger pine, western larch, and various species of willow alder, dogwood, aspen, mountain mahogany, maple, and oak. These species are found in successive zones which may be called the "lodgepole-pine zone," the "yellow-pine zone," and a still lower zone of which no single tree is characteristic, usually known as "Upper Sonoran." The great number of shrub species and herbs characteristic of the places where the extensive studies were conducted will be readily understood by anyone familiar with the great range of plant life found where the various trees just mentioned grow.

In this wide altitudinal and latitudinal range the more important soil as well as climatic conditions were covered. The main soil types were: Sandy loam, clay loam, decomposed pumice, volcanic ash with varying amounts of organic matter, and soils of various textures originating primarily from basaltic, granitic, sandstone, and calcareous rocks.

ESTABLISHMENT OF THE PLOTS.

In all cases the seed was scattered broadcast, either with a machine or by hand. The proportion of seed used in mixed sowings was similar to that employed in the detailed reseeding work. The amount of seed required to produce a full stand, when a single species was sown, will be discussed elsewhere. In most situations the soil was given no culture before the seed was scattered. In general, the areas were closely grazed prior to seeding, and in the main inexpensive methods of planting were employed, namely, harrowing in the seed with a brush or wooden peg harrow, or trampling it in by sheep.

RESULTS.

COMPARATIVE SUCCESS OF THE VARIOUS SPECIES.

Of the 449 experiments observed during the calendar year 1911, 168, or 37.42 per cent, were failures; 112, or 24.95 per cent, were partial successes; 71, or 15.81 per cent, were fully successful; 64, or 14.25 per cent, were undeterminable at the end of the season; and in the case of 34 experiments, or 7.57 per cent of the total, the results were not definitely declared. Grasses were used in most of these experiments. The following table is presented to show the results in the case of single or pure sowings.

TABLE 1.—*Results of seeding to grasses.*

Name of species.	Number of projects.	Failures.		Successes and partial successes.		Undeterminable at end of season.	
		Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
1. Timothy	87	22	25.29	56	64.37	9	10.34
2. Kentucky blue grass	44	22	50	14	31.82	8	18.18
3. Smooth brome	43	10	23.26	25	58.14	8	18.60
4. Redtop	36	14	38.89	12	33.33	10	27.78
5. Orchard grass	22	11	50	4	18.18	7	31.82
6. Italian rye	8	5	62.5	3	37.50	0	0
7. Tall meadow oat grass	5	2	40	0	0	3	60
8. Canada blue grass	4	3	75	1	25	0	0
9. Perennial rye	4	2	50	2	50	0	0
10. Grama grass	2	2	100	0	0	0	0
11. Canadian wheat	1	1	100	0	0	0	0
12. Hard fescue	1	0	0	0	0	1	100
13. Broom grass	1	1	100	0	0	0	0
Total	258	95	.....	117	.....	46	.....
Average per cent	.....	.....	36.82	.....	45.35	.....	17.83

Table 1 shows that by far the best results were secured with timothy, 64.37 per cent having been successful or partially successful. It will be observed that this species was employed in 87 projects, from the Canadian to the Mexican boundaries. Despite the fact that the results of a part of these experiments were not declared, over three-fifths gave good returns.

Next in the category of successful results are: Smooth brome grass with 58.14 per cent, perennial rye grass with 50 per cent, Italian rye grass with 37.5 per cent, Kentucky blue grass with 31.82 per cent, and redtop with 33.33 per cent. It is interesting to note that the more drought-resistant species, notably smooth brome grass, perennial rye grass, etc., rank among the first in the successful seeding. The figures given in Table 1 are comparable in each case to the results obtained where these species were seeded in mixtures. As far as the returns show, all trials of meadow oat grass and hard fescue gave negative results.

Very few of the nongrasses yielded satisfactory returns. Those worthy of consideration are white and alsike clovers and alfilaria. Of the trials with white and alsike clover, 41.67 and 14.82 per cent,

respectively, gave partly or wholly satisfactory returns. In the case of alfilaria, 28.57 per cent of the experiments gave good results. The alfilaria, however, requires a high temperature during the growing season and therefore it can not be successfully introduced except in the lower elevations. In southern California, where this plant flourishes, it fails to produce much herbage above an altitude of 6,000 feet. In the Northwest it should not be sown above 3,000 feet elevation.

While the locations at which the best results from reseeding have been obtained are not shown in Table 4, it may be stated, allowing for local variations, that the best returns were secured in the Northwest and the poorest in the more arid Southwest. No species yet tried can be economically introduced in the hot, dry foothills of California, Arizona, and New Mexico, where the lands are distinctly arid.

SPRING VERSUS AUTUMN SEEDING.

The most convenient way in which to note the time at which seeding has yielded the best results is by means of curves showing the percentages of successful and partially successful experiments and of failures during the spring, summer, autumn, and winter periods, classifying the months as follows: Spring—March, April, and May; summer—June, July, and August; autumn—September, October, and November; and winter—December, January, and February.

Plate II shows emphatically that autumn is the most satisfactory time to sow, the spring period coming second; the summer and winter periods are the most unsatisfactory. By months, October and May, in the order named, proved the most satisfactory. The reason why fall seeding, and especially the month of October, yields the best results, aside from the more elaborate root development produced, is doubtless primarily the fact that all plant activities have ceased at that time, and thus a weak autumnal growth and subsequent winter killing is avoided. Then, too, during the dormant period the seeds are worked into the ground by physical agencies, and when conditions for germination become favorable the seeds are not only well planted but the seed coats are softened and germination takes place promptly and simultaneously.

CAUSES OF FAILURE.

The causes of failure in the unsuccessful experiments are numerous. Often several factors are operative in bringing about unsatisfactory results, and it is sometimes difficult to determine which is the most potent.

The six chief causes of failure, in the order of importance, are as follows:

1. Lack of soil treatment.
2. Drought.

3. Wrong selection of species.
4. Spring sowing.
5. Excessive competition with native vegetation.
6. Wrong time of sowing (other than spring).

It is interesting to compare the following statement as to the chief reasons for only partial successes:

1. Spring sowing.
2. Lack of soil treatment.
3. Drought.
4. One or more species unadapted.
5. Excessive competition with native vegetation.
6. Wrong time of sowing (other than spring).
7. Overgrazing.
8. Excessive moisture for species sown.

Within the altitudinal limits at which the conditions governing growth are favorable, and on the lands adapted to the growth of cultivated forage plants, the factors which bring about failures are largely preventable. The lack of soil treatment, which, it will be noted, leads as a factor in the causes of failure, is, by the proper handling of the lands, preventable in virtually all cases; the drought factor, except possibly during seasons of unusual weather conditions, may be eliminated by the judicious selection of the lands to be seeded; wrong selection of species is largely avoidable when the soil, moisture conditions, altitude, and the requirements of the species used are known; failure due to spring and summer seeding should be avoidable since it is generally known whether or not enough precipitation is received during the growing period to insure continued vigorous growth.

It will be noted that, in the main, the same causes which were operative in the case of failures were also responsible for only partial successes; and that while the arrangement of the chief causes in the two cases is somewhat different, the lack of soil treatment is of vital importance in both.

Consideration of further results of the extensive experiments will be deferred until an account of the intensive studies has been given, when the conclusions reached as a consequence of both series of studies can be most intelligibly presented.

INVESTIGATIONS IN THE WALLOWA MOUNTAINS.

These investigations, conducted on a series of plots at various elevations, were planned with a view to obtaining precise data upon physical and climatic conditions which might be expected to play an important part in determining the success or failure of each experiment.

The studies were originally confined to 15 main plots having an average area of about 4 acres, of which 10 were in the whitebark pine and 5 in the lodgepole pine zone. Both in the spring and autumn of 1908, 1909, and 1910 several additional small plots were seeded to grasses and clovers at high and medium elevations.

CLIMATIC CONDITIONS.

The amount of precipitation during the growing season was notably greater in the high mountains than at lower levels. In 1909, which was about an average season, the mountain bunch-grass ranges in the whitebark pine zone (elevation about 7,500 feet) received 7.45 inches of precipitation during the main growing season, which, at that altitude, is about three months long, mainly July, August, and September. The lands of medium elevation, about 4,500 feet, in the lodgepole pine zone, a region which enjoys a growing season of about four and one-half months, received during July, August, and September 5.51 inches precipitation. On the ranges of the yellow-pine zone (elevation about 3,000 feet), the precipitation received during the same period was 3.63 inches. In subsequent seasons the relative amounts were about the same.

The temperature in the whitebark pine zone as compared with the two lower zones was found lower by several degrees; the evaporation also was less, and consequently the transpiration demand on the vegetation was less.

DESCRIPTION OF THE PLOTS.

The largest plot, 20 acres in area, was selected on a severely overgrazed tract, on what is known as Stanley Range, lying at an altitude of about 7,300 feet on a ridge which at one place broadens out into a plateau about a mile in width. The area was seeded to a mixture of timothy, redtop, and Kentucky blue grass. The amount of seed sown per acre was as follows: Timothy, 8 pounds; redtop, 3 pounds; and blue grass, 4 pounds. The seed was worked into the ground by driving a band of sheep in a compact body twice over the area.

As shown in figure 2, the topography is smooth, and the whole area slopes westerly from 3° to 6°. The soil is a light clay loam, having a depth of from one to several feet, underlain by a layer of basaltic rock mixed with more or less soil. In places this rocky layer is exposed, forming small "scabs" or "scablands." The water-retentive power of this soil is good, though the surface layer becomes rather dry early in the season.

The whole area was originally covered with mountain bunch grass (*Festuca viridula*), but it is now almost barren. The most abundant perennial plant now is sickle sedge (*Carex umbellata brevi-*

rostris). A number of inconspicuous annuals are scattered over the entire area in more or less profusion. In a number of small patches where moisture is abundant there is a dense growth of alpine redtop (*Agrostis rossæ*), slender hair grass (*Deschampsia elongata*), a number of different species of sedges and rushes, and a small amount of mountain timothy (*Phleum alpinum*). Subalpine fir, Engelmann spruce, and whitebark pine occur in restricted clumps over the area, occupying, as shown in figure 2, less than 5 per cent of the land.

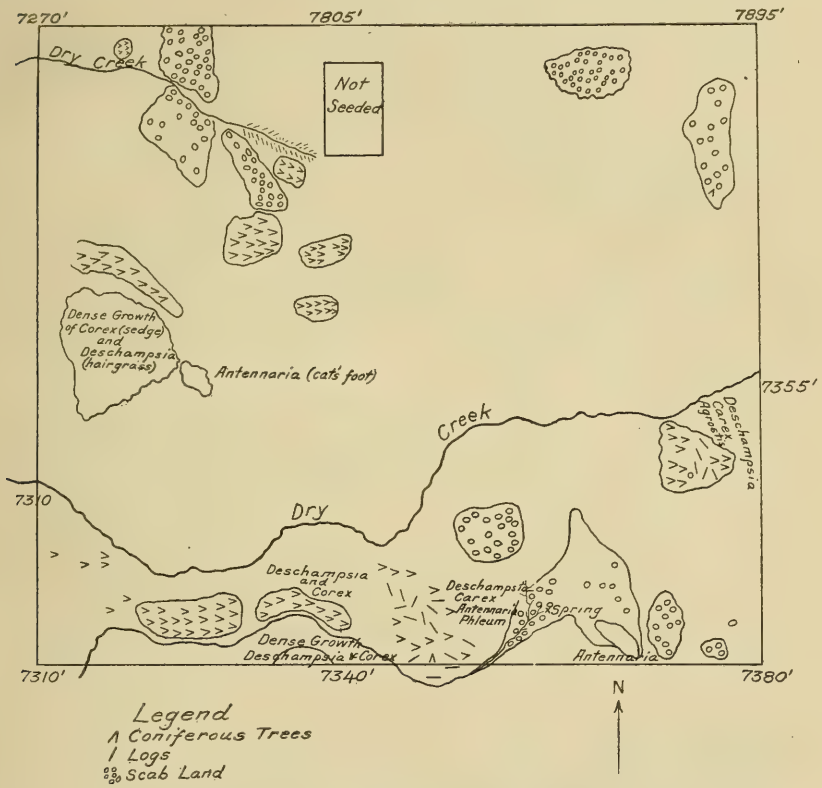


FIG. 2.—Chart of the largest area selected for reseeding experiments, main pasture, Stanley Range.

Three other reseeding plots, one a fourth of an acre and the other two a half acre each in size, were established on Stanley Range, the same species being seeded as on the larger plot, and, in addition, smooth brome grass and alsike and white clovers. The only difference in the physiography of these plots as compared with that of the larger area is in the slope and exposure. The two half-acre areas have a southeastern aspect, one with a gradient of 12° and the other of 15°. The quarter-acre plot has a uniform eastern slope of 6°.

On Sturgill Range, at an altitude of about 7,600 feet and in the same general type as the Stanley Range, 5 acres were seeded. The area selected is an old bed ground lying in a shallow cove. The ground is smooth, except for occasional narrow ruts caused by erosion in the spring. The general aspect is toward the southwest, with a gradient of 5° to 6°. The area formerly bore a heavy growth of mountain bunch grass (*Festuca viridula*), but is now bare of vegetation save for a few scattered tufts of yarrow or wild tansy, sedge, and needle grass (*Stipa minor*) and a small clump of alpine fir and

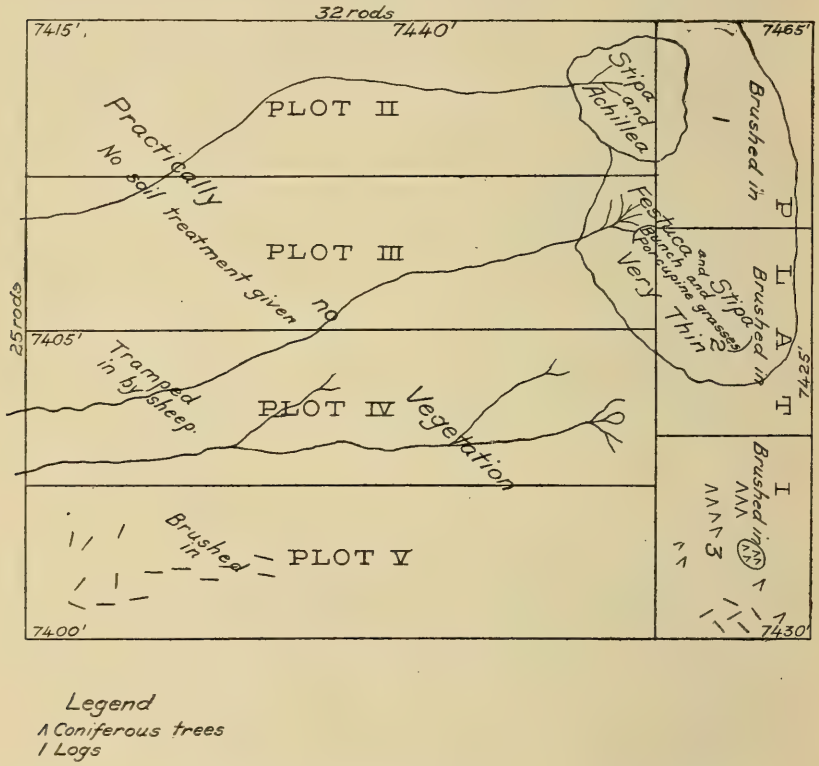


FIG. 3.—Chart of the seeding experiment on the Sturgill Range.

whitebark pine in plot 1. (See fig. 3.) Small portions of plot 1 and plot 5 are covered by logs. The soil is a deep basaltic clay loam similar to that on Stanley Range, but richer in organic matter. Soil samples taken at a depth of 8 inches at various times during the main growing season gave an average moisture content of 27 per cent. Although sheep have been bedded on the ground for several years, the soil has not been packed to a great extent.

Plot 1 contained 1 acre. It was divided into three subplots, each of one-third acre. Subplot 1 was seeded to timothy at the rate of 9 pounds per acre; subplot 2, to redtop at the rate of 15 pounds per

acre; and subplot 3, to Kentucky blue grass at the rate of 21 pounds per acre. In each case the seed was planted by the use of a brush harrow. Plots 2, 3, 4, and 5, each 1 acre in area, were seeded to a mixture of timothy 5 pounds, redtop 4 pounds, Kentucky blue grass 5 pounds. No soil treatment was given plots 2 and 3. Plot 4 was trampled by sheep after seeding, and plot 5 was thoroughly brushed with a pine-tree harrow. The arrangement of the plots and the native vegetation are shown in figure 3.

On what is known as the Bear Creek experimental range, an area of 4 acres was seeded to a mixture of 5 pounds timothy, 4 pounds red-

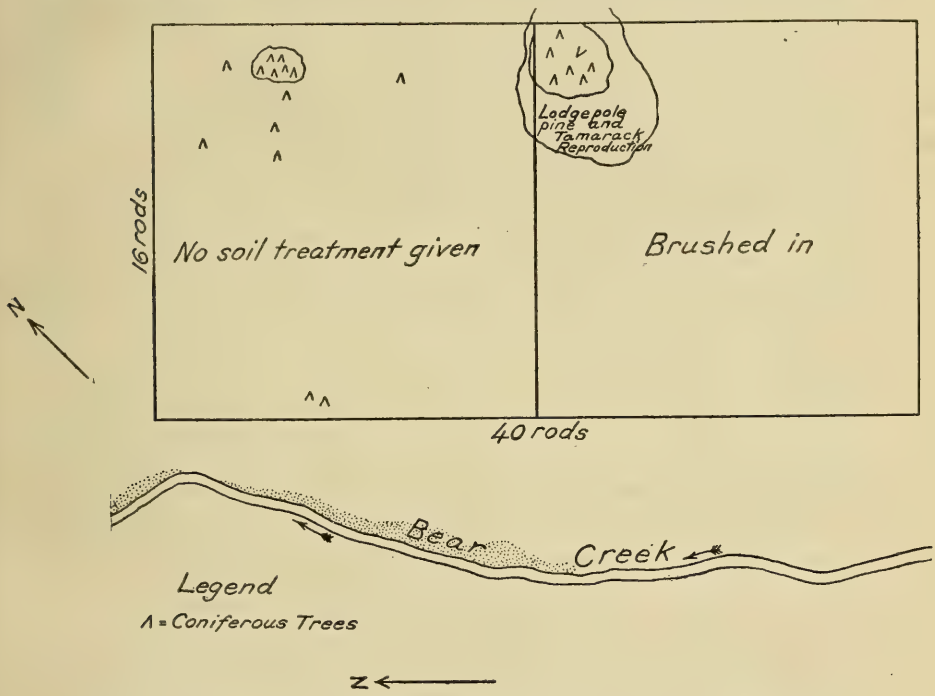


FIG. 4.—Chart of the seeding experiment at Bear Creek Station, altitude 4,800 feet.

top, and 5 pounds Kentucky blue grass. One-half of the area was brushed in and the remaining 2 acres were left untreated.

The area selected, as shown in figure 4, is a strip 16 rods wide by 40 rods long, in the bottom of the Bear Creek Canyon, lying within a few rods of the stream. The elevation of Bear Creek at this point is about 4,800 feet. Ridges rise abruptly on both sides to a height of 2,000 feet above the creek. The seeded area is smooth and practically level. The soil is a deep, black, slightly clayey loam of alluvial character. The minimum water contained in the soil taken at a depth of 8 inches during the summers of 1908, 1909, and 1910 was 16 per cent. The land originally bore a heavy stand of timber, of which western larch, Engelmann spruce, yellow pine,

lodgepole pine, lowland fir, Douglas fir, and aspen were the most abundant species. About 20 years ago practically all the timber was killed by fires, leaving the ground strewn with semidecayed logs. Chaparral, which is very dense on adjoining areas, is rapidly invading some of the land. Coniferous reproduction, consisting chiefly of spruce, lowland fir, tamarack, and lodgepole pine, is abundant, and saplings are making an unusually rapid growth, indicating favorable conditions. There is a sparse stand of grasses and grass-like plants, those most abundant being pine grass (*Calamagrostis suksdorfii*), two sedges, and a number of weedy annuals. The herbaceous vegetation had been closely grazed by cattle at the time that the seeding was done.

Additional reseeding plots were established in the less rugged portion of the Wallowa Mountains, near what is called the "Billy Meadow" country. The elevation of this locality (5,000 feet) is slightly greater than that of the Bear Creek area, but in the same vegetation type. The lands selected had been overgrazed to a marked degree, but the soil was still fertile and capable of high carrying capacity. Timothy, Kentucky blue grass, redtop, and alsike clover, were used. Both pure and mixed seeding was done on these plots, the proportion of seed being virtually the same as that given for other plots where the same species were employed. The alsike clover was seeded at the rate of 8 pounds per acre. In some of the plots the seed was harrowed or brushed in; in other cases no soil treatment was given. The viability of the seed of the species used in these studies was determined under controlled conditions in the Seed Testing Laboratory of the United States Department of Agriculture. The results of these tests follow:

TABLE 2.—*Viability of the seeds of the species sown.*

Kind of seed.	Duration of test.	Germination.
	Days.	*Per cent.*
Smooth brome grass	14	72.5
Kentucky blue grass	31	44.5
Redtop	9	88.0
Timothy	13	81.5
Alsike clover	14	90.0
White clover	26	88.0

The germination tests show that with the exception of Kentucky blue grass, which germinated only 44.5 per cent after a test of 31 days, the viability of the seeds sown was as good as might be expected. Owing, however, to the likelihood of "heating" at the time of harvesting, viability of Kentucky blue grass is usually below that of the other species here employed.

In the case of all the plots described the seed was scattered in the autumn. To test the relative merits of spring and autumn planting additional small plots adjacent to those seeded in the autumn were seeded just as the last snow was disappearing in the spring. In all of this work the seed was scattered broadcast, in some cases with a hand seeder and in other cases by hand. Either when sown pure or to a mixture, the hand seeder, shown in Plate I, figure 1, was highly satisfactory in getting an even distribution of the seed. A machine of the kind shown in this plate does not exceed 5 pounds in weight, is easily portable and compact, and can readily be adjusted to regulate the amount of seed to be sown. A 10 to 12 foot swath is covered by a machine of this kind, and one man can sow from 25 to 35 acres per day.

RESULTS OF THE INTENSIVE STUDIES.

In general it may be said that the factors chiefly instrumental in bringing about unsatisfactory results in reseeding are (1) wrong time of sowing; (2) inadequate planting of the seed; (3) use of species unadapted to the conditions; (4) excessive altitude; (5) soil which is either too shallow or of undesirable physical structure and chemical character, or which has too small or too great a supply of moisture.

In presenting in detail the results of the intensive experiments there will be discussed: Spring and autumn sowing; the merits of different methods of soil treatment; growth requirements and characteristics of the forage species in question during the time of establishment; the restriction of reseeding due to altitude; and how to judge, by the native vegetation, lands suitable for reseeding.

SPRING VERSUS AUTUMN SEEDING.

A study of spring-seeded and fall-seeded plots established on contiguous lands in a number of different situations showed the autumn-sown areas far superior to those sown in the spring (1) in the time of germination, (2) in the period required for all the seed to germinate, (3) in the development and vigor of the seedlings, and (4) in the subsequent seedling loss due to adverse conditions, which determines the final stand.

The most striking examples of the advantage of autumn sowing were observed on plots established on well-drained mountain meadow lands where the surface layer of soil is friable and has a tendency to dry out excessively early in the season. A measure of the merits of spring and autumn sowing on such lands is shown in Plate II. Under the same climatic and soil conditions grass seed—timothy, Kentucky blue grass, smooth brome grass, redtop, etc.—sown in the

fall germinated from 5 to 12 days earlier than seed sown in the spring on top of the snow or on a saturated soil just as the last snow of the season disappeared. With species having thick, hard, and more impermeable seed coats than grasses, as in the case of clovers, there was much more difference in the time of germination. In some few situations the seed, both of clover and grasses, sown in spring tided over to the following spring, when good germination was secured. With such delayed germination much of the seed is consumed by birds and rodents or removed by the wind and other agencies.

Both the root development and the aerial growth of the plants originating from autumn-sown seed was about double that of plants from seed sown in the spring. The significance of this fact appears in a heavy and relatively early loss of seedlings from spring sowing due to drought. In many situations the difference in the depth of the root system resulting from autumn and spring seeding has resulted in a satisfactory stand on the one hand and complete failure on the other.

It may be definitely stated from the results obtained that in the Wallowa Mountains spring seeding, except possibly in the situations where the soil is well supplied with moisture throughout the season and where the seed may decay if allowed to lie dormant for a long period, has no advantages over autumn seeding. On the other hand, spring sowing has grave disadvantages. The seed germinates late and over a long period; much of it is lost owing to delayed germination; the seedlings are shallowly rooted and are liable to serious injury from drought; and superabundant moisture interferes with cultural methods of planting.

By sowing in the autumn the above difficulties are virtually eliminated. Seed should not be sown so early in the autumn that it will germinate before winter. If it germinates in the fall the little seedlings are likely to succumb to drought, if the season is dry, or their growth is so slight that little reserve food is stored in their roots, and the plants make only a weak growth the following spring. Where winters are severe it is best to sow after vegetative growth ceases and before the heavy winter snows begin. Then the seed will be protected by the snow until the time of germination.

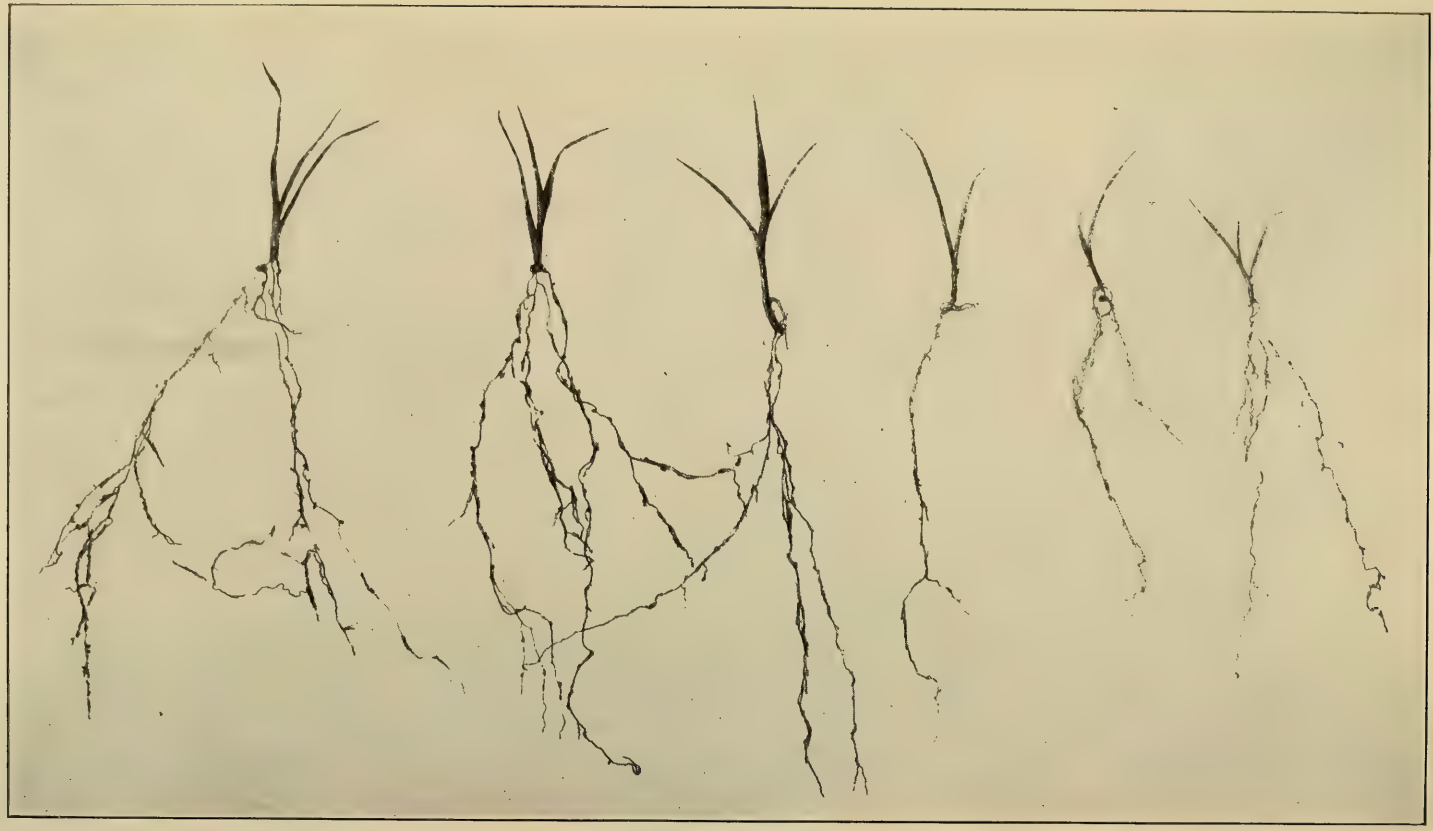
ADVANTAGES OF THOROUGH PLANTING.

In order to know which of the inexpensive methods of soil treatment used will give the most satisfactory results in reseeding it was highly important to secure definite information as to the density of the seedling stands secured on the various plots. The difference in the abundance of seedlings was evident on some of the plots, or on parts of them, by mere observation, but to get definite compari-

FIG. 1.—A HAND SEEDER IN USE ON AN OVERGRAZED RANGE AREA.

FIG. 2.—A BRUSH HARROW IN USE. WITH MATERIALS AVAILABLE THIS IMPLEMENT CAN BE CONSTRUCTED IN AN HOUR.

FIG. 3.—A WOODEN PEG "A" HARROW FOR USE IN PACKED SOILS; IT CAN BE CONSTRUCTED BY ONE MAN IN THREE HOURS.



A Comparison of the Root Development of Timothy Sown in the Fall and Sown in the Spring.

Specimens on the left show average development from fall sowing; those on the right from spring sowing.

sons on the plots as a whole it was necessary to make actual counts. This was done by noting the number of seedlings within a number of sample areas 40 inches square. Table 3, which follows, shows the results.

TABLE 3.—*Seedling stand on the different plots.*

Location.	Plot No.	Treatment.	Number of unit area counts.	Seed sown.										Seeded singly or in mixture.
				Timothy.			Redtop.			Blue grass.				
				Subplot.	Pounds per acre.	Average number seedlings per square meter.	Subplot.	Pounds per acre.	Average number seedlings per square meter.	Subplot.	Pounds per acre.	Average number seedlings per square meter.		
Sturgill Range, elevation 7,600 feet.	I	Brushed in.	32	1	9	15.7	2	15	26.8	3	21	22.0		Singly.
Do	II	Trampled by sheep.	17	...	5	19.6	...	4	15.4	...	5	3.6		Mixture.
Do	III	...do	20	...	5	18.2	...	4	16.0	...	5	4.2		Do.
Do	IV	Untreated	20	...	5	13.5	...	4	9.2	...	5	2.5		Do.
Do	V	Brushed in.	15	...	5	43.6	...	4	36.8	...	5	12.4		Do.
Bear Creek station, elevation 4,800 feet.	I	...do	10	...	5	49.2	...	4	19.8	...	5	15.4		Do.
Do	II	Untreated.	10	...	5	20.8	...	4	6.4	...	5	4.4		Do.
Stanley Range, elevation 7,300 feet.	I	Trampled by sheep.	31	...	8	16.0	...	3	5.3	...	4	2.1		Do.
				Alsike clover.										
Do	II	Brushed in.	11	1	8	11.7	...	.....	.....	...	.....	.....		Singly.
Do	II	Trampled by sheep.	9	2	8	6.8	...	.....	.....	...	.....	.....		Do.
				White clover.										
Do	II	Brushed in.	10	3	8	14.4	...	.....	.....	...	.....	.....		Do.
Do	II	Trampled by sheep.	10	4	8	11.2	...	.....	.....	...	.....	.....		Do.

The figures show that on the plots sowed to a single species (Plot I, Sturgill Range) the best stand was secured from redtop, the bluegrass plot ranking second in abundance of seedlings. The reason for the sparse stand of timothy, as compared with the other two species on these particular areas, was primarily the superabundance of native vegetation, which prevented much of the seed from coming in contact with the soil.

Comparing the brushed, trampled, and untreated plots, it will be seen that in every case the best stand was secured on the brushed areas, the trampled plots ranking second and the untreated plots having the poorest stand. It will be noted, however, that the plots given no treatment have a correspondingly better stand of timothy seedlings than of any other species. In the case of the untreated plots this may be explained by the greater weight of the timothy seed than that of the other species.

On Stanley Range the plots were all trampled in, and consequently seedling counts were made only in the large pasture. Here the stand was not as good as on the plots just discussed. This area was much drier during the early part of the summer than the area on Sturgill Range, and a notably larger percentage of the seedlings succumbed as a result of insufficient moisture. However, in all situations the loss of seedlings was greater and occurred earlier in the season where the soil was not treated than where the planting was thorough.

The relative merits of the cultural methods used and of no soil treatment, as evinced by the density of the fully established forage stand secured on uniform autumn-sown habitat, are shown in Table 4.

TABLE 4.—*Relation of forage yield to cultural methods.*

Species.	Soil treatment.	Forage cover (10 maximum).
Timothy	Brushed	4 to 6
	Trampled	2 to 7
	No treatment	0 to 4
Redtop	Brushed	1 to 4.5
	Trampled	1 to 4
	No treatment	0 to 2
Kentucky blue grass	Brushed	4 to 7
	Trampled	3 to 4.5
	No treatment	1 to 2

Table 4 shows markedly that in the case of all three species the best stand was secured on the brushed plots, the areas trampled by sheep after sowing being second. (See Pl. III, figs. 1 and 2.) These results are doubtless accounted for by the fact that the seed on the brushed plots is more uniformly and not too deeply covered. On the plots given no soil culture whatever the density of stand secured was very inferior.

Both harrowing or brushing and trampling the seed in by the sharp-cutting hoofs of sheep have special advantages. On densely packed and stiff soils brushing or even running over the surface with the A wooden-peg harrow is not nearly so effective as trampling by sheep. On the other hand, using sheep as harrows will not bring about the good results that brushing will, other things being equal, on denuded areas, where there is no vegetation to bind the surface, and where the soil is friable.

Other conditions being the same, it is evident that better returns from reseeding are ordinarily obtained on denuded lands than on areas where the soil is tightly bound by roots. While lands that support a dense stand of vegetation indicate a fertile soil and usually good conditions for growth, it is often difficult to get cultivated plants started on such areas, first, because of the difficulty of thoroughly working the seed into the ground without thorough cultiva-

tion; and, second, because of the inability of the young plants to compete successfully for moisture and light with the hardy, well-established, and deeply rooted native vegetation. On such lands reseeding will usually not pay.

Effective cultural implements.—Owing to the character of the land to be seeded, one instrument may be preferable in one locality and another in a different situation. Accordingly, the means of construction both of the brush and the A wooden-peg harrow is here given.

The brush harrow pictured in Plate I, figure 2, consists of five saplings or tops of whitebark pine or any other available stiff-leafed species, pines or spruces being preferable, cut into lengths of about 6 feet and laid parallel to each other at intervals of about a foot, depending upon the spread of the branches. These tops are held together, as in a vise, between two 5-foot crosspieces, the lighter of which is uppermost. The brush ends are usually trimmed a little to insure a tight fit all around. The crosspieces may either be lashed together by wire or rope or secured by wooden pegs inserted through bored holes. The whole can be readily dragged over the ground by a rope attached to the saddle horn. A swath of 5 to 6 feet is covered by this harrow. On denuded areas this crude implement did such effective work that usually only one brushing was necessary to cover the seeds, but where there was more or less grass or other vegetation to bind the soil even repeated brushing was not highly effective. On such lands, where the original vegetation is not so dense as to make reseeding impracticable, an A wooden-peg harrow was found more effective.

As shown in Plate I, figure 3, this is a simple device, the framework of which is composed of three small logs, about 5 or 6 inches in diameter, cut into lengths of about 5 feet. These are hewn down with an ax in order to present a flat surface, and are fitted together into the shape of a letter A, or of a triangle, and the ends secured by spiking with wooden pegs or by wiring. With a brace and bit holes of about 1 inch in diameter are made through the logs at intervals of about 5 inches, and teeth, made from such branches as may be available, cut into uniform lengths of about 6 or 7 inches, are driven through. This harrow also may be readily dragged over the ground by a rope attached from the apex to the horn of the saddle. An ax and an inch auger are the only tools needed for its construction. This implement takes about a 4-foot swath.

The use of sheep in planting.—Sheep are found even more efficacious in working up partially vegetated and closely packed soils than the A wooden-peg harrow. A band of sheep driven in a compact body once or twice over an area after seeding was found to leave no part of the surface soil unstirred. On bunch-grass lands, for example,

where many of the tufts had died out, the tussocks were often torn asunder by the sheep passing over them a couple of times. In loose soils, as stated, there is danger of getting the seed planted too deeply by the employment of this scheme. This difficulty may be largely obviated by driving the band over the area before as well as after scattering the seed. By so doing the loose hummocks and elevated points are mostly smoothed down before the seed is scattered, and too deep planting is thereby at least partly eliminated. Even then, however, the forage stand secured on areas of loose soils where the seed was trampled in was not usually as dense as where harrowing or brushing was employed, but much better than where no soil treatment was given subsequent to sowing.

COMPARATIVE MOISTURE REQUIREMENTS AND ROOT DEVELOPMENT OF THE SEEDLINGS.

During the first year of growth—that is, during the seedling period—a rather marked variation was found to exist in the ability of the species in question to become established. This fact does not necessarily mean that one species is more drought resistant or can take more water from a given soil than another, but rather that there is a difference in the depth, spread, and general development of the root system through which the water is secured.

When young, the species of similar growth-form and of the same age produced very nearly the same height growth. It was also found that the species which naturally flourish in the drier habitats produced roots of similar development so far as concerned their depth and spread. It was found, however, that the ratio between the height growth and the depth of the root in the case of species which naturally prefer medium moist soils was different from that developed by species which prefer moist habitats. As a concrete example, four grass species, smooth brome grass, timothy, Kentucky blue grass, and redtop, which are known to have different moisture requirements, were grown in a common habitat, and at the end of the fifth week after germination the respective species were carefully examined to ascertain the average depth of the root development. Smooth brome grass had extended its roots to a depth of 3.1 inches, while timothy, Kentucky blue grass, and redtop had made an average root development of 2.7, 2.5, and 1.9 inches, respectively. The habitat selected was amply moist up to the date that the measurements were made, and during the period in question each species functioned normally at all times.

As the season advanced, the soil, even to the lower depth of the roots, gradually became so dry as to completely eliminate all the seedling plants. Redtop, the plant requiring the greatest amount of moisture in the superficial layer, died from drought at some time or other during the first six weeks of growth. Kentucky blue grass, next

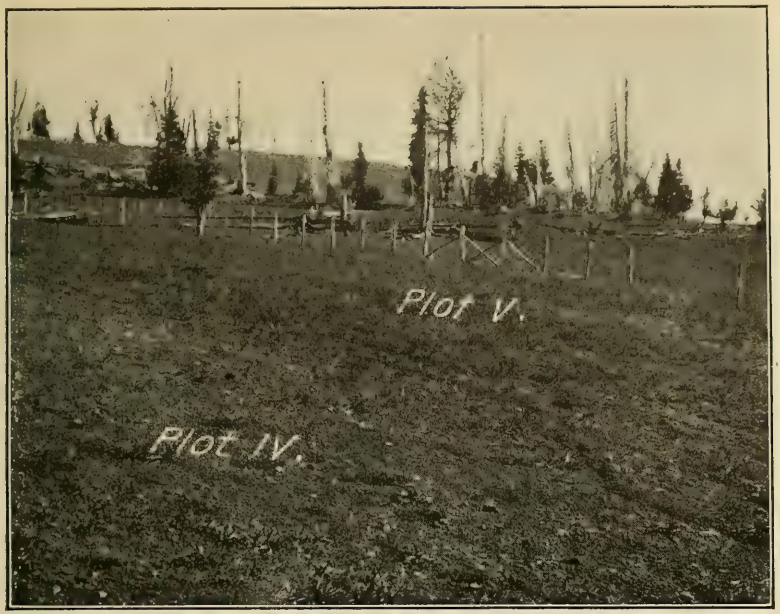


FIG. 1.—THE DIFFERENCE IN DENSITY OF SEEDLINGS FROM DIFFERENT CULTURAL METHODS AT THE END OF THE FIRST YEAR OF GROWTH; PLOTS IV AND V, STURGILL RANGE.

On Plot IV the seed was trampled and on Plot V the seed was brushed in. The dominating species is timothy.

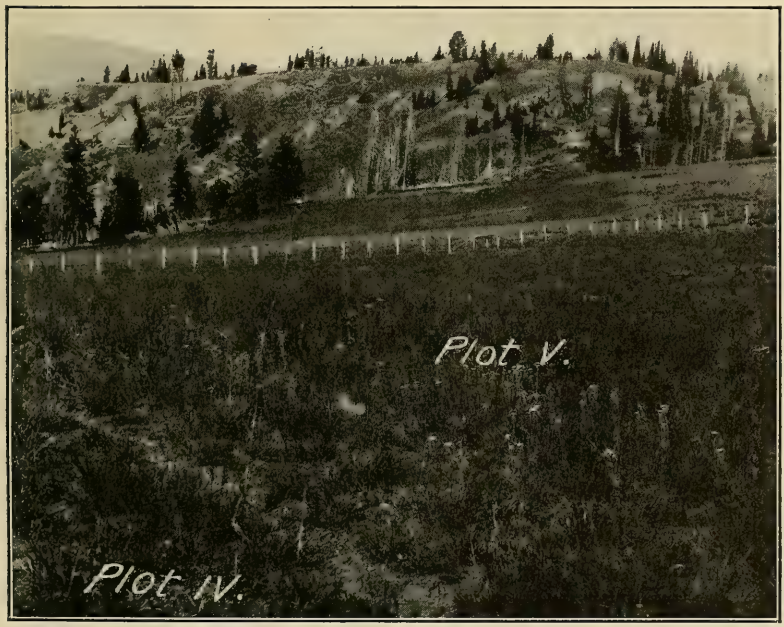


FIG. 2.—ANOTHER VIEW OF PLOTS IV AND V, SHOWING THE GROWTH AT THE END OF THE SECOND YEAR.

On the trampled area 40 per cent of the ground is covered by grass and on the brushed area 60 per cent.

COMPARATIVE MERITS OF DIFFERENT CULTURAL METHODS.

THE RESULT OF RESEEDING.

A burned-over area on Bear Creek where pine grass and weeds have been replaced by timothy, redtop, and blue grass. This area was seeded in the fall of 1907; the picture was taken in the fall of 1909.

to show distress for lack of water, was killed mainly during the seventh week of growth. As evinced by its repeated wilting during the warmer part of the day, timothy showed a more serious condition than brome grass, which, as stated, was more deeply rooted than timothy. During the latter part of the eighth week all the timothy plants were killed, while some few brome-grass seedlings persisted until the end of the tenth week. During this entire 10-week period no precipitation, aside from that accumulated in the form of dew, was received. Meanwhile, the minimum soil water content varied from 4 to 9 per cent. A soil moisture content of 4 per cent marked the lower moisture limits at which these plants could exist in the habitat in question.

A comparison of the time and degree of wilting of the various species and their ability to recover from wilting further substantiates the above classification as to moisture requirements. The species which are able to recover from one wilting to another may tide over the serious drought period, which may be broken at any time by the necessary precipitation. The time of recovery and subsequent vigor varied with the different species. During the fore part of the drought period all species usually began to recuperate between about 4 and 7 o'clock p. m. each day. As the season advanced the time of wilting among the species became notably prolonged and more irregular. The more deeply rooted plants, smooth brome grass and timothy, during the first few weeks varied but slightly in the time during which wilting began, while redtop and Kentucky blue grass would in many cases become limp two hours earlier and would not recover from this condition for several hours after deeper-rooted species had resumed the normal condition.

There is no doubt that the ability of a plant to recover from wilting when in a soil of low water content depends upon the vigor of the species, which, in turn, is largely determined by the depth of the root system by means of which the moisture is secured. Each time during wilting the root hairs in contact with the drier soil particles are doubtless killed, and the gradual elimination of these moisture-absorbing surfaces results in earlier and more severe wilting each day and finally, through the destruction of most of the root hairs, brings death to the plant.

RELATION OF ALTITUDE TO RESEEDING.

The uppermost limits at which seeding was found to yield good returns and the comparative yields at different elevations may best be shown by comparative measurements of the average height growth, density of stand, amount of seed yield, time of the flower stalk production and seed maturity, and the viability of the seed crop of the three closely studied species, timothy, Kentucky blue grass, and redtop. The areas compared are as similar as could be

found locally at wide altitudinal range. The lands were seeded simultaneously with seed from the same source, and the soil was given identical treatment. The results are presented in the following table:

TABLE 5.—*Relation of altitude to reseeding.*

Species.	Height growth at—		Density of stand based on scale of 10 at—		Estimated yield at—		Time of—				Viability of seed crop at—	
							Flower stalk production at—		Seed maturity at—			
	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.
	In.	*In.*			*Tons.*	*Tons.*					*P. ct.*	*P. ct.*
Timothy	15	39.0	4	9	½	2	Aug. 5–20	July 1–15	Sept. 1 to end of season.	Aug. 1–15	12.0	86.0
Kentucky blue grass.	9	15.5	3	7	1/10	½	Aug. 1–20	June 20–July 5.	...do....	July 15–Aug. 10.	9.5	36.5
Redtop	11	23.0	2	5	1/10	½	Aug. 10–28	July 10–30	Sept. 10 to end of season.	Aug. 10–25	8.0	74.0

A glance at Table 5 shows that there is a striking difference in the forage yield in the two situations, the ratio being approximately 4 to 1 for all three species.

This wide contrast in production is due to the difference in the density of the stand and in the height growth. The density bears the relation of 7 to 3 at 4,800 feet and 7,800 feet, respectively, while the height attained by the different species at 7,800 feet is over 100 per cent less than that produced at an elevation of 4,800 feet. This contrast in growth is further shown in Plates V and VI by natural-size photographs of average stands of timothy at 3 years of age, at which time full development has been attained.

Wide differences, of high importance from the standpoint of natural reseeding of the introduced plants, exist in the production and viability of the seed. It will be observed, for example, that the flower-stalk and the seed-maturing periods begin five weeks and five and one-half weeks earlier, respectively, in the situation of lower elevation. The lateness at which the seed crop matures at 7,800 feet makes it impossible, except for the individual plants which put forth the flower stalks unusually early, to produce viable seed. This accounts in part for the fact that the average germination of the three species in the higher elevation is 9.8 per cent, as opposed to 64.8 per cent in the lower habitat.

Owing to the low yield, due to the sparseness of the stand and to the poor height growth made, and the small amount of viable seed produced at an elevation of 7,800 feet, it is evident that this is the maximum elevation at which reseeding should be attempted in the Wallowa region.

RELATION OF SOIL ACIDITY TO RESEEDING.

Throughout the mountains are found areas, usually limited in extent, either so situated that the soil is saturated with water the year round or of such poor drainage that the water accumulated in the spring does not dry out of the soil until late in the growing season. Owing to poor drainage, the rank plant growth usually produced, and the continuous accumulation of organic matter, the soil in such habitats is often acid or sour in varying degrees.

The soil in the densely vegetated grass, sedge, and rush bogs is almost invariably strongly acid. In some such localities more than 30,000 pounds of lime would be required to neutralize an acre a foot in depth.[1] Areas characterized by huckleberries and heaths are also invariably strongly acid. The soils of the willow and alder lands, which are often fairly well drained, are likely to be less sour.

From a number of isolated plantings of the cultivated forage species experimented with, it became evident that in the sour soils clovers (alsike and white clover tested), Kentucky blue grass, and even timothy grew much less luxuriantly than redtop. Where the lime requirement was no more than 4,000 pounds per acre, alsike clover, in spite of the abundant water supply, died early in the first season, and Kentucky blue grass struggled along, making very slow growth. In the more acid soils timothy also showed signs of distress and did not develop nearly to the extent that it did in the better-drained soils less than a hundred yards away. The feature of greatest interest was the behavior of the roots. Except for redtop, each of the species tried made a very meager root development in the sour soils, and instead of penetrating to a normal depth and spreading naturally, the rootlets curved and twisted in a most unusual fashion, as though in search of a different type of soil.

A study of the growth of cultivated forage plants in sour soils shows rather conclusively that alsike and white clovers and Kentucky blue grass are not adapted to such habitats; that timothy does not make its best growth in sour soils; that none of the other species included in this general study, similar in habits to timothy and Kentucky blue grass, succeed; but that redtop makes a prolific aerial and root growth. Such lands are frequently densely vegetated with plants inferior for forage purposes, and owing to the matted surface and the entanglement of long root stocks running under the surface of the ground, it is often difficult to get redtop started. When a stand is once secured, redtop is able to compete successfully with the native plants.

In deciding on the plants that may give the best results in reseeding moist meadows, and more especially marsh lands and bogs, it is

[1] In agricultural practice a soil having a lime requirement of 5,000 pounds for neutrality is considered very acid.

not necessary to determine their acidity by chemical analyses. The acid condition of the soils may be recognized by noting the kind of plants growing on them.

In coves where aeration of the soil is largely prevented by saturated moisture conditions during the greater part of the year, the vegetation is entirely made up of plants that are adapted to living in strongly acid soils. The Wallowa mountain lands of this character support a number of locally well-known grasses such as mountain timothy (*Phleum alpinum*), slender reed grass (*Cinna latifolia*), tufted hair grass (*Deschampsia caespitosa*), marsh pine grass (*Calamagrostis canadensis*), and tall meadow grass (*Panicularia nervata*). (See Pl. VII, fig. 1.) Intermixed with these are a number of sedges, rushes, and weeds, the more common of which are tall swamp sedge (*Carex exsiccata*), water sedge (*Carex festiva*), wood rush (*Juncoides glabratum*), cone flower (*Rudbeckia occidentalis*), and false hellebore (*Veratrum viride*). (Pl. VII, fig. 2.) The genera here mentioned indicate, in a general way, an acid soil, though all the species of a single genus do not necessarily prefer sour soils. Where these plants and those of similar habits are found in abundance, and where the soil remains in a high state of moisture during most of the year, it is relatively certain that clovers, Kentucky blue grass, and even timothy, and indeed all cultivated plants used in this investigation, except redtop, will not succeed. Redtop, on the other hand makes its most luxuriant and prolific growth in these lands.

Even in some of the better drained acid soils where huckleberries and heaths or willows and alders occur in abundance, redtop is often the most satisfactory species. These plant associations, except possibly in the case of dense stands of huckleberries, usually indicate a less strongly acid soil than the grass and sedge marshes. Where lands of these types are so situated that drainage is not seriously obstructed, timothy, which is found to succeed in moderately sour lands, is often a valuable species for reclaiming them. All the experiments indicate that timothy, next to redtop, will give the best returns on such soils. This is one of the instances where a mixed seeding of redtop and timothy is justifiable. If the soil proves too sour for timothy or too dry for redtop, the chances are favorable to the establishment of one or the other of the species.

The intensive studies have therefore established:

(1) That under usual conditions reseeding will be most successful if performed in the fall after vegetative growth has ceased.

(2) That inexpensive soil treatment either in the form of brush or tooth harrowing or by the trampling of sheep is highly important.

(3) That in endurance of drought smooth brome grass, timothy, Kentucky blue grass, and redtop grade in the order named from high to low resisting power.

THE EFFECT OF ELEVATION ON THE DEVELOPMENT OF TIMOTHY.

An average 3-year-old timothy stand grown at an elevation of 4,800 feet. Note the length of the panicle, the rank culm development with its bulb-like base, the many leaf blades, and the deep and spreading root system. (Natural size.)

THE EFFECT OF ELEVATION ON THE DEVELOPMENT OF TIMOTHY.

An average 3-year-old timothy plant grown at an elevation of 7,300 feet. Note the low stature, the small panicle, the slender culm without the bulb-like enlargement at the base, the few and short leaf blades, and the undeveloped root system. (Natural size.)

FIG. 1.—A TYPICAL MOUNTAIN MARSH.

Minam Meadow, altitude 5,000 feet, covered mainly with tall swamp sedge. Redtop is adapted to such a situation, but can be established only with difficulty because of the densely matted soil surface.

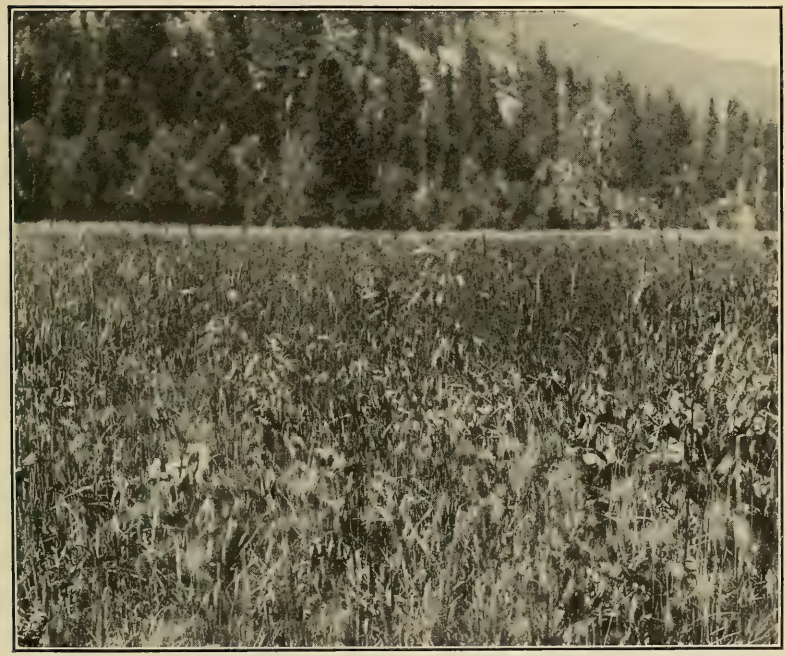


FIG. 2.—TIMOTHY AND REDTOP ESTABLISHED.

A moist meadow in the Wallowa Mountains, 5,200 feet elevation, originally covered with various plants of low forage value which have been almost completely supplanted by timothy and redtop.

FIG. 1.—A PACK TRAIN STARTING INTO THE WALLOWA MOUNTAINS.
This illustrates the difficulty of transportation, which tends to preclude the use of agricultural implements.

FIG. 2.—A DEPLETED RANGE IN THE WALLOWA MOUNTAINS, 7,600 FEET ELEVATION.
This shows the upper limits at which seeding will pay. The trees have their characteristic open stand, but at slightly higher points, where the trees become dwarfed, reseeding will not pay.

(4) That in the Wallowa Mountains an altitude of 7,800 feet marks the highest limit at which reseeding is likely to pay. This is about 500 feet below timberline.

(5) That on acid soils redtop or redtop and timothy should be sown.

(6) That acid soils may be recognized by the type of vegetation present.

Further conclusions of practical importance, based upon the experience derived from both the intensive and the extensive experiments, will be presented in the following pages.

SELECTION OF SPECIES.

In introducing cultivated forage plants on the range the judicious selection of the species to be sown is a matter of first importance. If species which are not adapted to the local conditions are chosen the cost of seed and labor is to no purpose.

The chief points to be considered are: The particular soil and climatic conditions in their relation to the requirements of the various species; the cost of the amount of seed required to establish a satisfactory forage stand; the time required, and the ability of the species to withstand grazing; and finally, the palatability, nutritiousness, and forage yield of the species.

HABITAT REQUIREMENTS OF THE SPECIES STUDIED.

In the selection of species possibly the most common and most serious mistake is made in not choosing those best adapted to local moisture and soil conditions.

From the standpoint of moisture requirements the species studied may be classed as of high, intermediate, and low requirements. The first group includes the plants that grow luxuriantly in wet meadows and saturated soils, poorly drained and consequently poorly aerated. The second group includes those which do best on well-drained and more porous soils, but which, though requiring a medium amount of moisture for their highest development, may do fairly well both in dry and moist habitats. The third group consists of species which thrive best on lands that are well drained at all times of the year. Table 6 gives the arrangement of the species under these heads.

TABLE 6.—*Water requirements of the species.*

Low.	Intermediate.	High.
Alfilaria.	Alfalfa.	Alsike clover.
Australian saltbush.	Alsike clover.	Orchard grass.
Blue grama grass.	Canada blue grass.	Red clover.
Bur clover.	Italian rye grass.	Redtop.
Hard fescue.	Japan clover.	White clover.
Mesquite.	Kentucky blue grass.	
Slender wheat grass.	Orchard grass.	
Smooth brome grass.	Perennial rye grass.	
Timothy.	Red clover.	
	Tall meadow oat grass.	
	Timothy.	
	White clover.	

It is not to be inferred that the above classification is absolute. Owing to the adaptability of some species to a rather wide diversity in soil-moisture conditions, a single species, as shown in the above table, may fall under two classifications. While the classification is necessarily general, it is believed that it will be helpful to stockmen in the judicious selection of species to be used, since it indicates what species may be used in locations of different moisture conditions. Some will succeed in both the medium and dry situations, and some in both the medium and wet.

As has already been pointed out, the acidity of the soil, as well as its physical structure and the corresponding moisture content, must be considered in selecting a species for a given area. Redtop, for example, makes the best growth and becomes permanently established on moist, poorly drained soils of strongly acid character. Timothy also does well on sour soils, but does not withstand the degree of acidity that redtop does, while clovers fail completely (for all practical purposes) in such habitats. On the other hand, Australian saltbush, aside from being a dry-land plant, is adapted to alkaline soils, which are antagonistic to the other species of low moisture requirements.

RELATIVE AMOUNT AND COST OF SEED PER ACRE.

SEEDING TO ONE SPECIES.

The way in which the seed is sown and the inexpensiveness of the soil treatment makes the cost of the seed itself the heaviest item of expense. The average cost per hundred pounds of choice seed of the various species, and the amount required per acre to secure a full stand on soils of high carrying capacity, follow:

TABLE 7.—*Amount of seed and cost per acre.*

Species.	Pounds per acre.	Cost per hundredweight.	Cost per acre.
GRASSES.			
Canada blue grass	20	$14.00	$2.80
Slender wheat grass	20	20.00	4.00
Hard fescue	15	15.00	2.25
Italian rye grass	20	6.50	1.30
Kentucky blue grass	20	20.00	4.00
Orchard grass	15	15.00	2.25
Perennial rye grass	20	7.00	1.40
Redtop	15	15.00	2.25
Smooth brome grass	20	15.00	3.00
Tall meadow oat grass	20	15.00	3.00
Timothy	8	8.00	.64
NONGRASSES.			
Alfalfa	8	10.00	.80
Alfilaria	8	80.00	6.40
Alsike clover	8	20.00	1.60
Australian saltbush	20	75.00	15.00
Bur clover	8	10.00	.80
Japanese clover	10	20.00	2.00
Red clover	8	25.00	2.00
White clover	8	25.00	2.00

The other items of expense are transportation, scattering the seed, and soil treatment. The first of these varies so widely, according to the means of transportation, distance, cost of labor, and horse rental, that no figures can be given. Where pack animals must be employed the cost is necessarily higher than if a wagon can be used; and where the stockman does the work the cash outlay is materially lessened, since, by owning his own work animals, wagons, etc., a high rental is eliminated, and in many cases work of this character can be done when other labor is not urgent. In the Wallowa experiments the seed was transported on the backs of pack animals for a distance of about 25 miles at an approximate cost of $2 per hundred pounds. (See Pl. VIII, fig. 1.) This cost is figured on the basis of $2.50 for the day wage of a man and $1 for horse rental.

With the use of a hand seeder a man can sow 25 acres per day, provided the area is in one tract. This makes a cost of 10 cents per acre. Hand sowing is considerably cheaper if an experienced man is available, but it is extremely difficult to get in this way an even distribution of light seed, like redtop and Kentucky blue grass.

If the seed is trampled in by sheep no expense is incurred. Brushing can be done at a cost of 25 cents per acre.

SEEDING TO A MIXTURE.

With species like Kentucky blue grass, the seed of which costs 20 cents per pound and which requires 20 pounds to the acre for a full stand, the cost makes extensive seeding prohibitive, except possibly under the very best soil and growth conditions. It is often a matter of economy to sow such seed in mixture with one or two of the less costly species. For example, a mixture of 9 pounds of Kentucky blue grass and 4 pounds of timothy per acre, which is sufficient seed to produce a full stand, will cost approximately half that of a pure seeding of 20 pounds of Kentucky blue grass. For range purposes generally, even though good returns may be expected, it is not deemed advisable to expend much over $2 per acre for seed and planting. Where growth conditions are favorable the original stand is sure to increase if the lands are not grazed too early and closely each year, and eventually the maximum carrying capacity of the land in question will be secured at a relatively low expense if the $2 per acre limit is adhered to.

Aside from the question of cost, it is sometimes expedient to seed to a mixture because of uncertainty as to what species a given meadow is best adapted, or because with a proper selection the grazing period may be lengthened and at the same time a variety of feed afforded. As a concrete example, where Kentucky blue grass, timothy, and redtop are seeded in mixture and each becomes established, the Kentucky blue grass is the first in the spring to produce a forage crop.

When this plant is at its maximum producing capacity timothy is just beginning to grow vigorously, and no flower stalks are produced until the blue grass begins to mature its seeds. Not until timothy has produced most of its flower stalks, after which it is not eaten with as much gusto as earlier in the season, does redtop come into evidence. It grows late and remains palatable until about the close of the mountain grazing season.

In addition, some species produce a good forage crop much sooner after seeding than others and live much longer. Timothy, for example, usually produces a fair forage crop the second year following seeding, and yields maximum crops up to about 6 years of age, after which its forage production usually decreases year after year.[1] Redtop, on the other hand, does not usually yield good returns until the fourth year after seeding, but when once established it is there to stay and may be depended upon to continue to produce good crops if growth conditions are satisfactory. True, in sowing to a mixture it is possible and entirely probable that the species to which the conditions are best suited may readily predominate and supplant the others, but in some habitats there is such a balance between species that none is forced out until age intervenes. Again, the ability of certain species to withstand adverse winter conditions is variable and one grass may be entirely killed out, possibly by somewhat unusual conditions, while the vitality of another may not be affected in the least. Thus, in artificial reseeding, time may often be saved and additional forage produced by mixture sowing.

In order that the reader may compare the cost of some of the most promising species used, both when sown pure and in mixtures of various proportions, the following summarized table is presented. Timothy, Kentucky blue grass, and redtop were used in these experiments, the cost of the seed being $5, $10, and $15 per hundred pounds, respectively. No cost of transportation is included. The costs of scattering the seed and of a given soil treatment were practically the same throughout.

[1] Records show that in a few cases timothy has yielded good returns for 10 consecutive years.

TABLE 8.—*Kind and amount of seed sown on each plot in fall of 1907, subsequent soil treatment given, and total cost per acre.*

STANLEY RANGE—7,500 FEET.

Area seeded.	Size of area.	Plot No.	Sub-plot No.	Kind of seed.	Pounds sown per acre.	Treatment after seeding.	Total cost per acre.
	Acres.						
Main pasture	20	I		Mixture	8	Trampled in by sheep	$1.40
				Timothy	8		
				Redtop	3		
				Kentucky blue grass	4		
Sedge-catfoot area	¼	II		Mixture		do	1.30
				Timothy	4		
				Redtop	4		
				Kentucky blue grass	4		
Mountain bunch-grass area.	1	III		Mixture		do	1.50
				Timothy	5		
				Redtop	4		
				Kentucky blue grass	5		

STURGILL RANGE—7,800 FEET.

Denuded bed ground	1⅓	I	1	Timothy	9	All brushed in	$0.80
	⅓		2	Redtop	15		1.85
	⅓		3	Kentucky blue grass	21		3.50
Do	1	II		Mixture		Trampled in by sheep	1.50
				Timothy	5		
				Redtop	4		
				Kentucky blue grass	5		
Do	1	III		Same as plot 2; same number pounds.		do	1.30
Do	1	IV		do		Untreated	1.30
Do	1	V		do		Brushed in	1.55

BEAR CREEK RANGE—4,800 FEET.

Burned over	2	I		Mixture		Brushed in	$1.75
				Timothy	5		
				Redtop	4		
				Kentucky blue grass	5		
Do	2	II		Same as plot 1; same number pounds.		Untreated	1.50

The amount of seed per acre given in Table 8, namely, 9 pounds for pure seeding of timothy, 15 for redtop, and 21 for Kentucky blue grass, has proven satisfactory. It is apparent in these sowings that the expense in securing a satisfactory pure stand of Kentucky blue grass and redtop is approximately four times and two times higher, respectively, than in the case of timothy. This is due both to the difference in the cost of the seed and to the amount required to produce a good forage crop; the seeding ratio for blue grass, redtop, and timothy was 5, 3½, and 2. In a mixture the expense is decreased in accordance with the proportion of timothy used.

INCREASE IN FORAGE PRODUCTION.

Timothy when sown at the rate of 8 pounds per acre will cost, for seed, including transportation, not to exceed 10 cents per pound, or 80 cents per acre. To this must be added the cost of 10 cents per

acre for scattering the seed and 25 cents for harrowing it in, making a total expenditure of $1.15 per acre.

The production of forage will vary from about one-half to 1½ tons per acre, depending primarily upon the altitude, soil, and climatic conditions. The value of the crop will depend upon local conditions. Even with a minimum of half a ton per acre it is a paying investment to seed. Cotton has shown that where a yield of only half a ton of timothy is secured, an acre of the land upon which his experiments were conducted would carry a 1,200-pound steer a little more than 30 days longer than it previously would. Thus he shows that if pasture is valued at 25 cents a head per month, it would, after the first year, give a return of more than 25 per cent on the cost of seeding. Besides, if the lands are properly handled so that the areas are not prematurely and too closely grazed, an appreciable forage increment of the introduced species may be expected from natural reseeding. This additional increment may often justify reseeding even when a low forage yield is originally obtained.

HOW TO GRAZE THE RANGE DURING THE RESTOCKING PERIOD.

During the period immediately following sowing the young plants ordinarily develop neither a sufficiently elaborate height growth nor strong and deep enough roots to furnish an appreciable increase in the forage and to withstand grazing. In the highest elevations, where the season is short and the temperature low, the seedling plants naturally make slower growth than in lower and warmer localities. Even in the lower elevations grazing is more or less seriously destructive during the first year. The loss from trampling is heaviest early in the season, but even in the autumn moderate grazing results in tearing and uprooting the young growth to a serious degree.

Cropping the plants is not disastrous to their development, unless it is done excessively or prematurely, but the seedlings are often pulled up or the roots are partly exposed when grazed, and as a result the plant suffers the following season. The lands seeded should therefore be wholly protected from stock during the first season subsequent to seeding. In the second year they may be moderately grazed, but stock should not be allowed on them until fall, when the root system has attained its full development for that season.

CONCLUSIONS.

WHERE RESEEDING IS PRACTICABLE.

The reseeding investigations show that the returns secured from sowing suitable cultivated forage plants on certain ranges fully warrant the expense. It is not to be presumed, however, that all overgrazed ranges can be successfully reseeded to cultivated plants. On the contrary, it is unquestionably true that existing conditions in the

major portion of the native grazing lands are antagonistic to the establishment of introduced plants. This is due primarily to one or all of three conditions: Excessive elevation, poor soil, coupled with insufficient moisture, or too much and too aggressive native vegetation.

ALTITUDINAL LIMITATIONS.

There are three chief causes of failure at high altitudes: First, only the strongest and best seeds can produce vigorous plants, and even this scanty original stand is often materially thinned out during the first season; second, the plants can ramify or stool out and spread only at a very slow rate; third, the plants produce such a small quantity of viable seed (note Table 5)that the possibility of increasing the stand from seed production is practically eliminated.

The altitude above which seeding to cultivated species should not be undertaken varies with latitude, and is approximately 3,500 feet higher in southern Arizona than in eastern Oregon. Because of this variation the character of the native vegetation is the best criterion for determining the maximum altitude at which reseeding is justifiable. As a concrete example, in the Wallowa Mountains, as previously shown, it has been found that the growing season is so short and the temperature is relatively so low at an altitude slightly exceeding 7,500 feet above the sea that no species thus far tried has made a satisfactory growth.[1] Here is the true timber-line tree—whitebark pine (*Pinus albicaulis*)—mountain bunch grass, heaths, huckleberry, and the lower zonal forms of arctic-alpine species. Where the whitebark pine becomes scrubby—timber line locally usually occurs slightly above 8,500 feet on north slopes—it invariably follows that the altitude exceeds that at which reseeding will pay. (See Pl. VIII, fig. 2.) The same principle applies to high mountain seeding in any locality, and it is safe to say that seeding to cultivated forage plants will not prove economically successful above the altitude at which the true timber-line species attain a good size and grow vigorously. Allowing for the influence of the different slopes and exposures on growth, timber-line trees do not usually make their maximum development when grown within 1,000 to 1,500 feet of timber line, and it may therefore be more specifically stated that seeding should not be attempted within 1,000 or 1,500 feet of timber line.

SOIL AND VEGETATION COVER.

Below 1,000 to 1,500 feet of timber line, then, the only areas suited to artificial seeding are those which have sufficient moisture and a deep soil with considerable organic matter, such as are found in

[1] At more southerly points, as in California, good stands of timothy have been secured at an altitude of 10,000 feet.

mountain meadows, moist parks meadowlike in character, and moist alluvial bottoms along streams. Soils of coarse physical structure so readily lose their water content through percolation and evaporation that in normal years the introduced seedling plants are almost invariably killed before the end of the first growing season.

In addition to the fertility of the soil the character and density of the native vegetation will help to determine what lands may profitably be seeded. Ordinarily seeding should not be attempted where the perennial native vegetation, such as a grass association, for example, covers about 60 per cent of the surface, for not only is the soil in poor condition to receive the seed, but the introduced species can rarely replace or compete with the more hardy established vegetation. Most of the moister and poorly drained mountain meadows are well vegetated with marsh grasses and succulent sedges, rushes, and weeds. It is often highly desirable to replace this type of vegetation with cultivated forage plants, owing to the low palatability and nutritiousness of the native species. But because of the dense and matted soil surface, a condition often coupled with sour or acid soil, few cultivated species have chances of becoming established in such habitats.

SPECIES RECOMMENDED.

On lands of medium moisture conditions and of average soil fertility no other species has given as uniformly good results as timothy. This plant can be introduced at the lowest cost of any of the highly desirable species; it gives a better yield under a diversity of range conditions than any species experimented with, and when once established it will withstand moderately heavy grazing relatively well.

In habitats of average moisture conditions where timothy flourishes, smooth brome grass, perennial and Italian rye grasses, and Kentucky blue grass, in the order named, are found to give good results. In the moister situations, especially on the poorly drained lands where the soil is inclined to be acid, redtop is far superior to any species so far tried. It will also do well in many situations where timothy thrives, but being less deeply rooted it requires, to attain its highest development, more moisture in the surface layer of soil. Redtop is notably less aggressive than timothy and many other species, but, reproducing as it does, mainly by root stocks, its establishment, while slow, is permanent. It is little liable to injury from trampling, even in wet situations, because of the dense entanglement of roots which bind the soil firmly.

Of the nongrasses, only alsike and white clovers can be recommended. The lands to be seeded to these species should be carefully selected, as neither very dry nor unusually wet soils are adapted to their growth. Saturated and poorly drained soils, which are in con-

sequence badly aerated and sour, are to be avoided or time and money will be wasted. Only the better-drained lands which are well supplied with soil moisture throughout the summer should be seeded to clovers.

WHEN TO SEED.

The climatic conditions, length of the growing season, and the character of the soil in a great measure determine the time that seeding should be done.

Under natural conditions in the mountains the seed crop is disseminated in the autumn and lies dormant until the soil warms up the following spring.

Within the altitudes at which temperature is favorable to growth, a single factor—drought—is instrumental in causing frequent failures. The soils of most mountain lands readily dry out near the surface. This condition results in the serious destruction of shallow-rooted seedlings. The deeper-rooted plants resulting from autumn seeding are less liable to serious thinning out than the seedlings with a shallower and less elaborate root system produced from seed sown in the spring.

Where the winter does not permit of growth, late autumn sowing should, in general, be resorted to. Care must be exercised to sow late enough so that no germination will take place until spring or the seedlings are likely to be heaved out of the ground and killed. The ideal time to seed is just before permanent snows come in the autumn.

If the situation is wet during most of the year, the seed may be dormant for a number of months, and is likely to decay before germination can take place. In such situations spring seeding should be resorted to. Again, in certain situations, especially in parts of the Southwest where the early spring period is habitually followed by dry weather and the inception of summer by heavy precipitation, the seed should not be scattered until late in the spring. In such regions the seed, if sown in the autumn, usually germinates as soon as the temperature is favorable, even though there is a small amount of moisture in the soil, and the tender shallow-rooted plants, being wholly dependent upon the surface soil for moisture, are almost invariably killed before the summer rains come.

METHODS OF SOWING.

The methods of sowing must be practical and inexpensive. The amount of work justified in sowing, preparing, and working the soil will naturally depend on the carrying capacity of the range and on the effectiveness of the operations. In many localities the mountains are so rugged and transportation is so difficult that the use of implements which the farmer relies on for tilling and working the soil is impracticable.

HOW TO SCATTER THE SEED.

Any means of scattering the seed which will distribute it evenly is satisfactory. Ordinarily a compact hand seeder should be used, but an experienced man can broadcast as well by hand; this method is certainly the most convenient, and doubtless the most economical. With either machine or hand method windy days should be avoided for the sowing. It is sometimes desirable to make double sowings, in which half the quantity of seed is sown in passing up and down the area and the other half by crossing at right angles to the first sowing.

SOIL TREATMENT.

It is too often assumed that grasses and other forage plants will grow anywhere and under all circumstances. The writer has no hesitancy in stating that he has yet to see the range conditions under which it will not pay to give some slight treatment to cover the seed, regardless of the kind of seed sown and the character of the soil. Of the various causes for failure the lack of soil treatment, either before or after sowing, was chiefly operative in 61 out of 168 unsatisfactory experiments. More failures were due to not covering the seed after sowing than to drought, wrong selection of species, and wrong time of sowing.

It is neither necessary nor desirable to cover the seed deeply, and expensive operations are rarely warranted. The investigations prove that some seeds, when planted more than half an inch deep, tide over the season or fail to germinate. The plants are more likely to become permanently established when the seeds are merely hidden below the surface of the ground than when covered more deeply.

Where the soil is friable and free from vegetation the brush harrow should be employed, but where compact and supporting vegetation, which binds the soil surface, the A wooden-peg harrow should be used. On such situations sheep driven in a compact body after sowing will plant the seed more thoroughly than any other of the methods tried. There is danger of too deep planting if sheep are used on the loose soils.

PROTECTION AGAINST GRAZING.

Regardless of the species sown, the lands should be protected from grazing animals until the plants have made sufficient development to withstand moderate grazing and trampling. In most places grazing should be entirely restricted during the first season after seeding, because both sheep and cattle destroy the young plants. In the autumn of the second year there is little danger of serious injury from moderate grazing.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.
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THE SOUTHERN CORN ROOTWORM, OR BUDWORM.

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

DISTRIBUTION.

The parent of the southern corn rootworm (*Diabrotica duodecimpunctata* Oliv.), or, as it is often termed, the budworm, is a yellow or greenish-yellow beetle having 12 black spots on the back, as shown in figure 1, *a*, from which its specific name, meaning "12-spotted," is derived. It is closely allied to the almost equally common striped cucumber beetle (*Diabrotica vittata* Fab.), and also to the parent of the even more destructive western corn rootworm (*Diabrotica longicornis* Say). Throughout the country east of the Rocky Mountains, extending from southern Canada southward to North Carolina, Tennessee, Arkansas, and Oklahoma, these 12-spotted and striped beetles together frequent squashes and pumpkins, often collecting in numbers in the blossoms. The 12-spotted species during late summer and fall also frequents, often in conspicuous numbers, the flowers of the various species of goldenrod (Solidago).

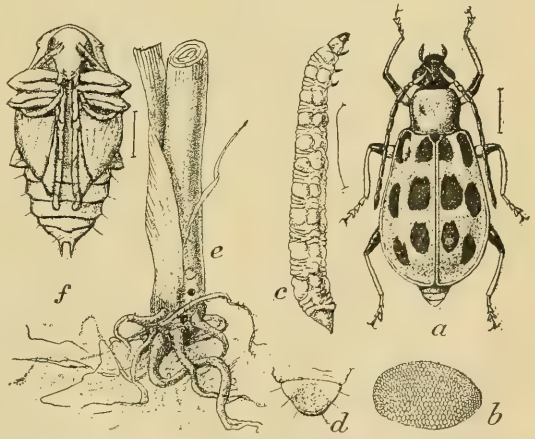

Fig. 1.—The southern corn rootworm (*Diabrotica duodecimpunctata*): *a*, Beetle; *b*, egg; *c*, larva; *d*, anal segment of larva; *e*, work of larva at base of cornstalk; *f*, pupa. All much enlarged, except *e*, reduced. (Reengraved after Riley, except *f*, after Chittenden.)

The larvæ (fig. 1, *c*) do not generally attack growing corn in sufficient numbers to cause any considerable injury, except perhaps

locally, north of the States mentioned in the preceding paragraph, although in 1890 some damage was done in the southern portions of Illinois, Indiana, and Ohio. Southward from the latitude of these States to the Gulf, and extending into Mexico, however, serious ravages are of more or less frequent occurrence. The author reared the beetles from larvæ that were attacking late-planted corn at La Fayette, Ind., during July and early August, 1888, though there was no serious injury to the crop as a whole. A larva was also observed by the author in the act of eating into a stem of young wheat in the field, on October 11, 1890, in the same locality, but the species is not of importance as a wheat insect.

FOOD PLANTS OF THE LARVÆ.

It is probable that the larvæ have attacked corn in the Southern States for at least a century or more. Prof. A. L. Quaintance recorded them as feeding not only on corn but also on the roots of rye, garden beans, and southern chess (*Bromus unioloides*) in Georgia,[1] working serious injury to both corn and beans. The author observed the larvæ attacking young wheat at La Fayette, Ind., October 11, 1890, while Mr. E. O. G. Kelly observed the same thing to occur at Wellington, Kans., October 2, 1907. March 1, 1909, Mr. T. D. Urbahns, at Mercedes, Tex., found larvæ one-half inch in length on the roots of young alfalfa and from these reared adults March 19. April 20, 1911, Mr. George G. Ainslie found larvæ in abundance feeding on the roots of young oats about Jackson, Miss. Adults from these larvæ emerged May 17. The same observer reared adults from larvæ found feeding on the roots of barnyard grass (*Echinochloa crus-galli*) at Hurricane, Tenn., on July 12, 1912, the adults in this case emerging on July 21. The grass upon the roots of which the larvæ were feeding grew up among and between corn that had previously been attacked and killed by the pest.

Dr. F. H. Chittenden[2] states that larvæ or pupæ have been observed at the roots of corn, wheat, rye, millet (*Panicum miliaceum*), southern chess (*Bromus unioloides*), beans, goldenglow (*Rudbeckia* sp.), and sedges of the genera Cyperus and Scirpus. Larvæ have been found and reared by him from about the roots of Jamestown weed (*Datura stramonium*) and pigweed (Amaranthus), and it is not improbable that they feed on these plants.

Prof. E. Dwight Sanderson[3] reported the larvæ working upon the roots of Johnson grass (*Sorghum halepense*) where these roots at the time appeared older than those of the corn. Under date of February 19, 1907, Mr. Dick Hatcher, of Fross, Tex., through Repre-

[1] U. S. Dept. Agr., Bur. Ent., Bul. 26, pp. 38–39, 1900.
[2] U. S. Dept. Agr., Bur. Ent., Circ. 59, p. 4, 1905.
[3] Entomological News, vol. 17, p. 213, June, 1906.

sentative Burleson of that State, informed the writer that the larvæ begin to work on the roots of Johnson grass during the latter part of July. They eat small holes under each joint, and by the latter part of November the roots are dead, and the Johnson grass, as he expressed it, "looks more like rotten sea grass than anything I can compare it to." This correspondent refers to their work on Johnson grass as being more beneficial than otherwise.

FOOD OF THE BEETLES.

The fully developed insect, or beetle (fig. 1, *a*), is a decidedly general feeder, eating readily almost any cultivated plant. A list of its food plants would be more interesting for what it did *not* include and if given in full would be entirely out of place in a publication of this character. Of grain and forage crops it has been observed to feed on corn, wheat, oats, rye, barley, buckwheat (probably), alfalfa, cowpea, soy bean, clover, timothy, milo maize, Kafir, pearl millet, vetch, Johnson grass, and rape.

DEPREDATIONS OF THE LARVÆ IN CORN.

Just when the southern corn rootworm, or budworm, as it is termed in the South, first began to attack corn is involved in obscurity. The writer several years ago[1] called attention to the fact that it was probably this insect to which a Mr. Charles Yancey,[2] of Buckingham, Va., referred when he described "a little white worm with copper-colored head" which, perforating the stalks of young corn "just below the surface of the ground," destroyed the growth. The budworm has certainly been accused of attacking corn in Virginia and other Southern Atlantic Coast States since long before the recollection of the oldest inhabitants. Quaintance[3] found excellent ground for believing that the pest was injurious in the cornfields of Georgia "many years before we find any reference to it in the literature of economic entomology." The first exact observations on the ravages of the larvæ (fig. 1, *c*) in growing corn, the identity of the pest being known at the time the observations were made, were by the writer and published shortly afterwards,[4] as follows:

> While in the South during the spring of 1886 we frequently heard of fields of young corn being seriously injured during some seasons by a small white worm which attacked the roots, usually during April. * * *
>
> On April 12 of the present year [1887] we were enabled to solve the problem by finding considerable numbers of these larvæ in the field of corn in Tensas Parish, La., where they were working considerable mischief by killing the young

[1] U. S. Dept. Agr., Insect Life, vol. 4, p. 264. 1892.
[2] American Farmer, vol. 10, p. 3, 1828.
[3] Loc. cit., p. 36.
[4] Report of the Commissioner of Agriculture for 1887, p. 148, 1888.

plants. As observed by us, their mode of attack differed from that of their northern congener in that they did not appear to attack the fibrous roots or bury themselves in longitudinal channels excavated in the larger roots. On the contrary, they burrowed directly into the plants at or near the upper whorl of roots, which almost invariably resulted in the death of the plant. These larvæ were much more active than those of *longicornis*, and on being disturbed would make their way out of their burrows and attempt to escape by crawling slowly into crevices in the soil, or if it were finely pulverized they would work their way down into it out of sight. Often several individuals, varying greatly in size, would be found about a single plant. On the 20th of same month, in another field, we found the larvæ much more numerous and the crop injured fully 75 per cent. Plants here, 6 to 8 inches high, were withering up and discoloring. Both of these fields had produced cotton the preceding year.

April 27, 1888, serious attacks to young growing corn were observed on Perkins's plantation, near Somerset Landing, Tensas Parish, La., and on May 12 similar depredations were noted in the vicinity of Madison, Ark. Still later the author found the larvæ attacking late-planted corn at La Fayette, Ind., July 12, and on July 14 of the same year 595 of these larvæ were collected and placed in rearing cages, adults from which appeared August 2 and 3. In all of the localities just given, except the last, the ravages were on corn growing in the low damp lands. Throughout the South and even farther north the soil of the lowlands and depressions in fields is of a darker color than that of more elevated areas, hence the statement of farmers and planters that the pest is more destructive on the "black lands." Prof. H. Garman [1] stated that to his personal knowledge corn had been injured during the years 1889 and 1890 in Virginia, Alabama, Mississippi, Louisiana, Arkansas, Kentucky, Illinois, and Ohio.

LOSSES CAUSED BY THE LARVÆ.

As showing the magnitude of the losses caused by this insect, especially throughout the South, illustrations have been selected from notes and correspondence of the bureau. During May, 1906, the writer found that one-fourth to one-third of the young corn growing on the farm of the State Hospital for the Insane, at Columbia, S. C., was being destroyed by these pests. The damage was being done more especially on the low parts of the fields with black or gray soils. Under date of July 15, 1907, Mr. R. F. Haynes, of Cheoah, N. C., stated that the corn crop had been ruined in many places during the spring by a worm that burrowed into the plant just above the base of the roots. Under date of March 20, 1908, Mr. D. P. High, of Whiteville, N. C., stated that farmers in his neighborhood had difficulty in getting a stand of corn on their bottom lands by reason of the attack of these worms. In his opinion it was becoming the greatest cornfield pest, especially in cold, wet

[1] Psyche, vol. 6, p. 30, 1891.

springs, like the one of that year. A similar complaint was received, April 10 of the same year, from Mr. J. L. Hughes, of Chatawa, Miss., who stated that he had replanted his corn three times and the worms were still destroying his crop, although the stalks of corn were 6 inches to a foot in height. Under date of May 24, 1909, Mr. Sidney Johnson, Boydton, Va., sent specimens of the larvæ, with complaints of serious ravages in his neighborhood. March 21, 1910, Mr. Milton Mountjoy, Shacklett, Va., stated that frequently the corn in his neighborhood was ruined over great areas by this pest. Under date of July 30, 1910, Mr. C. L. Foster, of Dalton, Ga., complained of great damage to the corn crop of his section by this pest, and forwarded specimens. In some instances the corn had been replanted three times and still was so badly injured that there was little prospect of a crop. Mr. J. O. Taylor, writing under date of August 17, 1910, from Bastrop, La., stated that early planted corn during that season had been seriously damaged and in many cases destroyed by this rootworm or budworm, which he clearly describes, as well as its method of attack. July 15, 1912, Mrs. A. E. Ballah, of Philippi, W. Va., complained that her corn had been ruined that year by this pest. Writing under date of February 1, 1912, from Brandon, Ky., Mr. Robert B. Parker, statistical agent, stated that corn was damaged 50 per cent in his part of the country by these worms. In some fields they had destroyed as high as 75 per cent of the crop. May 27, 1912, Mr. George G. Ainslie found a portion of a cornfield near Hurricane, Tenn., that had been damaged fully 95 per cent by these larvæ. Under date of December 4, 1912, Mr. G. M. Goforth, county demonstrator, writing from Lenoir, N. C., stated that this worm caused a loss of thousands of dollars every year in his (Caldwell) county.

HABITS OF THE LARVÆ.

The actions of the very young larvæ are in a sense forecasted by the observations made by Quaintance on the method of oviposition. No one else appears to have observed the method of oviposition in the open fields, but Quaintance has found that the stylus-like ovipositor of the female is pushed down into the soil to a depth of from one-eighth to one-fourth of an inch and held there until the egg is forced down the extensible oviduct. This requires usually but a few seconds, and after moving a short distance the beetle may deposit another egg in the same manner.[1] Quaintance further states that larvæ, placed on the roots of corn at one end of a root cage, after the destruction of this corn made their way through the soil to a

[1] Mr. R. A. Vickery, in North Carolina, found that eggs were deposited in the soil by females in confinement without reference to the corn plants growing therein.

plant 10 inches distant. He also observed that larvæ may descend from 8 to 10 inches below the surface of the soil in search of food.

These observations are substantiated by Mr. George G. Ainslie, who studied the habits of the larvæ in the field at Hurricane, Tenn., during May, 1912. In this case, upon digging up the injured corn plants he found that the roots and stem below the ground were grooved, furrowed, and perforated. In many instances there was a distinct perforation into the base of the plant which cut off the crown, thus destroying the central leaves. The larvæ were found either in the partly decayed kernel or along the underground stem in the earth. Only occasionally were the larvæ found with their heads in these holes in the stem. Mr. Ainslie experienced difficulty in finding these larvæ, it being necessary to dig over the earth thoroughly for a considerable distance around each plant, some of the larvæ being found 4 inches from the injured plant and at a depth of 3 or 4 inches. The author also had observed this habit in the young larvæ in previous years, and there is always difficulty in reconciling the number of larvæ one can obtain in badly infested fields with the damage clearly to be charged to them. In many cases the hole made in the plant is not clean-cut, as shown in figure 1, *e*, but has somewhat the appearance of having been simply bruised. This is probably the work of the young larvæ, while the clean-cut hole is the work of those individuals that are larger and more fully developed.

The larvæ of the species under consideration, aside from the work while very young, as described by Mr. Ainslie, eat directly through the outer walls of the base of the plant into the heart of the plant, usually just above the base of the roots, as shown in figure 1, *e*. The term "rootworm" is somewhat of a misnomer, because these larvæ are not usually found in the roots, and as a rule do not feed within them, as is the case with the allied western corn rootworm (*Diabrotica longicornis*).

OVIPOSITION.

The females, which have passed the winter in the adult stage, commence egg laying soon after the first warm weather of spring. The statement of Quaintance that the eggs are usually all deposited within the space of two or three days, while perhaps true as a rule, is not entirely borne out by the observations of others. For instance, Mr. R. A. Vickery at Brownsville, Tex., found that one female deposited 102 eggs during January 18, 19, and 20; another female deposited 22 eggs, 9 on January 19 and 13 on January 28. There does, however, appear to be a tendency on the part of the individual female to complete oviposition within a few days; and this feature in the life history is of considerable economic importance, as it shows that the egg-laying season for the individual in spring is not long drawn

out and that therefore remedial measures will be more effective than they would be otherwise. It has been generally observed, however, as between different females, that some contain eggs much less advanced than others, so that while the time required for the oviposition of a single individual may be very short, some individuals may have finished the process before others have begun. Even under such circumstances the egg-laying period can not be said to be exceptionally protracted.

SEASONAL HISTORY.

While it is possible that the insect may occasionally pass the winter as larva or pupa these instances have been observed too rarely to be considered otherwise than abnormal. Throughout the entire country, from Brownsville, Tex., northward, the insect normally passes the cooler months in the adult stage.

In southern Florida and southern Texas, where the insect remains active throughout the winter, the generations are but indistinctly defined. Northward, however, the species has a definite period of hibernation.

Mr. Vickery has observed the sexes pairing in North Carolina in November, and the author observed this at La Fayette, Ind., September 18, 1888, while Mr. Kelly made a similar observation at Manhattan, Kans. Mr. T. D. Urbahns found larvæ about half an inch in length in the roots of alfalfa at Mercedes, Tex., November 1, 1909, from which two adults developed November 19. Mr. Vickery has observed the males to fight each other most strenuously.

From the foregoing it would seem that pairing may sometimes take place during the late fall prior to the spring oviposition. Certain it is that many of the females are filled with fully developed eggs in very early spring, and, as will be shown, they have been frequently swept from wheat and oats, where they were observed to be feeding, before corn has even been planted.

This early appearance and feeding of the adults has been observed by Mr. Vickery at Winston-Salem, N. C., March 23, on rye, and at Statesville, N. C., March 29, on wheat; by Mr. Urbahns at Santa Maria, Tex., March 6, on oats; by Mr. George G. Ainslie at Nashville, Tenn., January 15, on wheat; and by Mr. C. N. Ainslie at Mesilla Park, N. Mex., April 1, on wheat. Adults were also observed by Mr. Urbahns at Mercedes, Tex., February 18, damaging young alfalfa by feeding on the leaves. At Lanes, Ga., March 3, and at Troy and Montgomery, Ala., March 5, they were observed by Mr. Vickery feeding on oats. Mr. George G. Ainslie observed them at Huntsville, Ala., April 14, feeding on oats; at Franklin, Tenn., February 15 to 18, feeding on wheat; and at Clemson College, S. C., February 20, feeding on oats. Quaintance reported that adults were in evi-

dence at Experiment, Ga., March 12, and that they had become abundant on alfalfa by March 28.[1]

While all of these data may at first seem of little consequence, they bear directly, as will appear later, on what now seems to be the planter's only hope of eliminating the ravages of the pest in his cornfields. It is fair to suppose that these females deposit eggs in the fields as soon as there is food for the larvæ, and it is the larvæ from these eggs that become so destructive in the fields of young corn, especially in the South. The reason they are not equally injurious in the North may perhaps be that by the time oviposition begins in spring and the larvæ have hatched corn has become too advanced in growth to enable these young larvæ to penetrate the stem at the usual point of attack.

Mr. Vickery, who followed the species through the season at Salisbury, N. C., in 1909, settled the question of the number of generations that occur annually at that point, finding that there are two. All of the observations of the author and those of several of the men working under his direction have shown that this is generally true throughout the country where the adult hibernates, but may not apply in the far South, where hibernation does not take place.

Prof. Quaintance, at Experiment, in central Georgia, noted the first appearance of the larvæ attacking corn on May 2. The first pupa was found May 8, and the first adult, evidently of the new generation, May 12.

Mr. C. L. Foster wrote as follows from Dalton, in northern Georgia, on July 30, 1910:

> I am mailing you a sample of worm that is causing great damage to the corn crop of our country. When the corn plant is small these worms bore into the center of the stalk underneath the soil and kill the plant by destroying the "bud." When the plants are larger they bore into some of the larger roots, but more generally into the stalks among the roots, which does not kill the plant outright, but injures it so that it rarely produces corn to amount to anything. The plat where these were found has been planted three times this season, and there are very few stalks now on the plat but what have been injured by the worms. The worms were not so plentiful on July 23 as they were on July 6, when the samples first sent you were collected.

From the foregoing letter it would appear that the second generation of larvæ were at work in late June and July in northern Georgia.

Mr. George G. Ainslie studied the larvæ, at that time 3 to 6 millimeters in length, at Hurricane, Tenn., May 27 to 30, 1912. They must have been full grown by the latter date, as none could be found in the fields June 5, and a recently emerged adult was taken on June 14.

The author observed full-grown larvæ attacking late-planted corn at La Fayette, Ind., July 12, 1888, and in such enormous numbers

[1] Loc. cit.

as to enable him, two days later, to collect nearly 600 for experimentation. It was simply impossible that these could belong to the first generation, as he had frequently observed adults feeding on wheat in the fields in April and early May. One beetle was observed eating out the opening buds of a cherry tree, April 17, 1888. Besides, adults were secured in early August from these larvæ found attacking corn in July. Other adults were observed in the same locality feeding on volunteer oats, December 14, 1888. Clearly there are two generations in the latitude of northern Indiana.

Prof. Quaintance,[1] in central Georgia, found that in one case the period from egg to adult extended from March 14 to May 21, a total of 68 days. In another case this period extended only from April 25 to June 5, or 41 days. Mr. Kelly, at Wellington, Kans., found that the period from egg to adult was 40 to 45 days, while Mr. Vickery, at Salisbury, in western North Carolina, found that this period extended from August 27 or 29 to October 24, or about 58 days.

From all available information it appears that the egg period varies greatly and may require from 7 to 24 days, the larval period from 15 to 35 days, and that of the pupa from 7 to 13 days.

NATURAL ENEMIES.

The Biological Survey has found *Diabrotica 12-punctata* in stomachs of the following 24 species of birds: Bobwhite, *Colinus virginianus* (found in 15 stomachs, one of which contained 12); scaled quail, *Callipepla squamata;* California quail, *Lophortyx californicus;* prairie chicken, *Tympanuchus americanus;* wild turkey, *Meleagris gallopavo;* yellow-bellied sapsucker, *Sphyrapicus varius;* red-headed woodpecker, *Melanerpes erythrocephalus;* nighthawk, *Chordeiles virginianus;* scissor-tailed flycatcher, *Muscivora forficata;* kingbird, *Tyrannus tyrannus;* phœbe, *Sayornis phœbe;* wood pewee, *Myiochanes virens;* western flycatcher, *Empidonax difficilis;* Acadian flycatcher, *Empidonax virescens;* Traill's flycatcher, *Empidonax trailli;* least flycatcher, *Empidonax minimus;* red-winged blackbird, *Agelaius phœniceus;* meadowlark, *Sturnella magna;* Bullock's oriole, *Icterus bullocki;* cardinal, *Cardinalis cardinalis;* rose-breasted grosbeak, *Zamelodia ludoviciana;* cliff swallow, *Petrochelidon lunifrons;* white-eyed vireo, *Vireo griseus;* robin, *Planesticus migratorius.*

The most efficient of the insect enemies of this pest is the fly *Celatoria diabroticæ* Shim. (fig. 2), the maggot of which develops within the body of the adult insect, killing its host. This parasite is not sufficiently abundant, however, to exert much influence in reducing the numbers of the insect.

[1] Loc. cit.

As far back in the past as 1888 the author found larvæ of a click-beetle, *Dasterius elegans* Fab., a close relative of the wireworms, under circumstances that led him to suspect that they were feeding on the budworm. Since that time, also, they have been taken in association with the larvæ of this species and, though never observed in the act, it is not at all unlikely that they do feed upon and destroy the budworm. Mr. Ainslie also encountered them associated with the budworm in his investigations of the latter at Hurricane, Tenn.

REMEDIAL AND PREVENTIVE MEASURES.

After having made its way into the crown of the young corn plant there is no remedy for the work of the pest. The shoot is ruined past all recovery, and the plant will only throw up worthless "suckers," which produce no ears and scant fodder. Fertility of the soil, or the lack of this, does not appear to have any influence on the amount of damage produced.

FIG. 2.—*Celatoria diabroticæ*, a fly parasite of the southern corn rootworm beetle. Much enlarged. (From Chittenden.)

Garman[1] states that of the seriously ravaged fields of corn examined by him one had been grown to tobacco and another to oats the previous year, while a third had been devoted to corn. The ravaged fields observed in Louisiana and Arkansas by the author had all been devoted to cotton the previous year. It would appear, therefore, that crop rotation has little if any effect in protecting fields of corn from the attack of the larvæ.

In the light of all the information at this time available it would seem that the farmer's only hope of relief from the ravages of this pest in the cornfields lies in so timing his planting in spring as not to subject his crop to severe attack. Quaintance, in central Georgia, secured eggs in March and April, 1900; Urbahns found young larvæ at Mercedes, Tex., March 1, 1909; George G. Ainslie observed larvæ attacking oats at Jackson, Miss., April 20, 1911. The author saw them damaging corn at Somerset Landing, La., April 12, 1887, and April 27, 1888; at Madison, Ark., May 12, 1888, and at Columbia, S. C., on May 4, 1906. At the last point the ravages of the larvæ were equally as serious as had been observed years before at Somerset Landing, La., and Madison, Ark., but at Columbia the writer was informed that corn planted after the middle of May escaped injury from the pest. Nearly all of the complaints of injuries from this budworm coming to us from the South refer to damage to the crop early in the season, March or April, although to the northward early May is

[1] Psyche, vol. 9, p. 45, 1891.

included. It would seem, therefore, that there might be a possibility of preventing much of the loss to corn growers in that section of the country by planting corn at a date that would bring the young plants above ground at a time after most of the eggs had been deposited, and not so late as to invite attack from the second generation, which is evidently abroad in the fields in late June and early July in northern Georgia and in July in northern Indiana.

Unfortunately heretofore the bureau has had neither the funds nor the men to carry out an extended investigation of this insect throughout its range of destruction. Now, with field laboratories at Columbia, S. C.; Nashville, Tenn.; Greenwood, Miss.; Brownsville, Tex.; and a temporary field station at Lakeland, Fla.—all equipped for this sort of work and in the hands of experienced men—we hope, with the cooperation of farmers and planters, to learn definitely whether it is not possible through practical measures to prevent the greater part of these ravages, and save or greatly reduce the losses caused by the budworm.

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THE AGRICULTURAL UTILIZATION OF ACID LANDS BY MEANS OF ACID-TOLERANT CROPS.

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INTRODUCTION.

In the past 20 years farmers have witnessed the development of what may be called a lime-and-clover literature and the growth of a corresponding agricultural practice. The scientific researches of various investigators published from 1867 to 1888 had demonstrated that leguminous plants through the bacteria of their root tubercles were able to take nitrogen from the atmosphere and that when a crop of these plants was plowed under the land was enriched as if by a corresponding application of manure.

In the northeastern United States the principal leguminous plant used in crop rotations had been red clover. The scientific confirmation of the popular belief that this plant had high value as a green manure greatly stimulated its use, the customary procedure being to plow under the clover turf after taking off one or two cuttings for hay. It was found, however, that if the land is acid in its chemical reaction red clover makes but feeble growth. If the chemical reaction is neutral or slightly alkaline and other conditions are favorable, heavy crops of red clover are produced. This consideration greatly extended the practice of applying lime, in order to neutralize the acidity of the soil and thus increase the manurial use of clover in crop rotations, over large areas of the older lands of the eastern United States.

It was found also that timothy, the chief hay grass of this region, was much longer lived and more productive in acid land when limed, and that wheat, one of the principal cereals, yielded much more heavily when treated in the same manner. Within the last few years the attempt in the acid East to cultivate alfalfa, the great hay crop of the alkaline West, has conveyed the same lesson in a still more striking manner. for alfalfa can not be grown satisfactorily in any soil, however fertile, which has an acid reaction. When grown

in the eastern United States alfalfa is not successful, except on calcareous soils, unless the natural acidity of the soil has been neutralized by suitable applications of lime.

One result of this advocacy of lime has been that in our anxiety to neutralize our acid soils and thus make them yield larger crops of such staples as clover, timothy, wheat, and alfalfa we have neglected to recognize clearly and to utilize the fact that some agricultural plants thrive as well in an acid soil as in an alkaline soil, or even better. It is proposed to discuss in this bulletin the bearing of soil acidity on agriculture and to direct attention to the utilization of part of our cheap acid lands through the development of rotations in which all the crops are acid tolerant, and the cost of making frequent and heavy applications of lime is therefore eliminated. These considerations are especially pertinent in sections where lime is expensive because of the remoteness of good commercial deposits of limestone. Where lime is not expensive the use of applications sufficiently heavy to neutralize the acidity of the soil is unquestionably profitable for many of the staple agricultural crops.

SOURCE OF SOIL ACIDITY.

One of the principal sources of soil acidity is decaying vegetation. The fallen leaves that carpet the floor of a forest are exceedingly acid. Freshly fallen leaves of some of our common trees show the following degrees of acidity, expressed in tons of ground limestone required per acre to neutralize a compact layer 6 inches in depth, estimated to weigh when dry 500,000 pounds, one-fourth as much as ordinary soil.[1]

TABLE I.—*Acidity of freshly fallen leaves, in terms of lime requirement per acre.*

Kind of leaves.	Acidity.	Kind of leaves.	Acidity.
	Tons.		*Tons.*
White oak	25	Sugar maple	22
Red oak	16	Tulip tree	14
Silver maple	22	Virginia pine	22

It is well known to farmers that on newly cleared timberland, not burned over, most crops do not grow well at first. A few, however, thrive in such situations, notably rye, buckwheat, and potatoes. All these are known to be acid tolerant. Table I, although representing conditions of acidity in excess of that actually existing in a cleared field, shows one of the sources of the acidity with which the plants have to contend and which is fatal to crops that are not acid tolerant. Another source of pronounced acidity in newly cleared timberlands is the freshly killed roots of the trees and underbrush.

[1] These acidity determinations were made by Mr. G. H. Baston, of the Bureau of Plant Industry, using phenolphthalein as an indicator, after boiling off the carbon dioxid.

It is also well known to farmers that, after a few years' preliminary culture in rye, potatoes, and buckwheat, virgin timberland with its humus-laden soil of a century's accumulation from rotting leaves and roots will sometimes produce heavy crops of timothy, wheat, and clover for one or two generations. The success of these crops shows that the soil has ceased to be acid. Again, when the store of humus derived from the forest has finally been exhausted after long years of ceaseless cropping, these soils revert to a condition of acidity, when lime is regarded as necessary to further agricultural prosperity.

What is this peculiarity of forest leaves by which they make the soil at one time acid, at another alkaline? It is worth while to consider this question, for its answer will throw new light on the practice of agriculture.

DECOMPOSITION OF LEAVES.

A layer of freshly fallen leaves on bare ground, moistened by rain, begins at once to decompose. A brown liquid leaches out of the leaves into the underlying soil. This liquid is acid. If the soil itself is naturally acid, its acidity is increased by these leachings. If the soil is sand, neutral in chemical reaction, it is made acid by the leachings from the leaves. But if the soil is alkaline from the presence of carbonate of lime, as in the case of ordinary loam of high fertility, the acidity of the leaf water is neutralized and its brown matter is precipitated, forming a portion of the black humus of the soil. On such an alkaline soil leaves decay rapidly from beneath and form a black, mellow, and very fertile leaf mold in which all traces of leaf structure have disappeared. Under such conditions the layer of leaf litter is always thin, often not lasting through the summer, and the transition from leaves to underlying mold is abrupt.

In sand, however, there is no such acid-neutralizing substance, and both soil and leaves remain in an acid condition unfavorable to complete decay. The next year a fresh fall of leaves brings a new accession of acidity, and the acid condition of the leaf litter becomes permanent. In a sandy oak or pine woods there is thus built up a tough mat of upland peat often several inches in thickness, composed of half-rotted leaves interlaced with the rootlets of trees and underbrush. Such peat mats are always acid, like ordinary bog peat.

One might conclude from what has been said that leaves unless treated with lime would remain acid throughout the process of decomposition. Such a conclusion, however, would be erroneous. Leaves when sufficiently decayed lose their acidity and of themselves produce a black mold that is not merely neutral in reaction, but sometimes markedly alkaline.

CHANGE FROM ACIDITY TO ALKALINITY.

The reason for this change from acidity to alkalinity lies primarily in the chemical composition of the leaves. From the beginning they are heavily charged with lime, as the following determinations in Table II will show:[1]

TABLE II.—*Percentage of lime in freshly fallen leaves, in terms of calcium carbonate, or ground limestone.*

Kind of leaves.	Percentage of lime.	Kind of leaves.	Percentage of lime.
White oak	1.12	Sugar maple	4.56
Red oak	3.08	Tulip tree	5.06
Silver maple	3.31	Virginia pine	.16

Soils containing such high percentages of lime as these leaves would be markedly alkaline, yet the leaves, as shown by the table on page 2, are strongly acid. It is evident from a consideration of both facts that the lime existing in the fresh leaves has gone into combination with their acid substances to the full extent of its ability to neutralize them, and that the acidity recorded on page 2 represents the acid substances in the leaves in excess of the amount already neutralized by the lime.

As the decomposition of the leaves progresses these excess acid substances are leached out or disorganized, the lime itself is released from its combinations, and a stage is reached where the lime is more than sufficient in amount to neutralize the remaining acidity. The mass has become an alkaline leaf mold. This change from acidity to alkalinity is often hastened by the development through bacteria of ammonia or other substances having an alkaline reaction.

The rapidity with which different kinds of leaves pass from the acid to the alkaline stage varies exceedingly. Leaves of silver maple in some tests have rotted so rapidly as to reach the alkaline state within a year. Red-oak leaves remain acid for several years, and pine leaves for many years.

ACIDITY OF GREEN MANURES.

Acidity determinations of several of the plants that are commonly plowed under for green manure give the following results, expressed in the weight of ground limestone that would be required per acre to neutralize a compact layer 6 inches in thickness.

[1] These lime determinations were made by Mr. J. F. Breazeale, of the Bureau of Chemistry, from duplicates of the same samples from which the acidity determinations on page 2 were made.

TABLE III.—*Acidity of green-manure crops to the acre, in terms of lime requirement per acre.*

Crop.	Acidity.	Crop.	Acidity.
	Tons.		*Tons.*
Alfalfa	13	Rye	11
Red clover	9	Broom sedge	11
Cowpea	10		

The excessive acidity of these green manures at the time they are first plowed under may be more clearly appreciated when one considers that the application of 2 to 3 tons of ground limestone per acre usually satisfies the requirements of an ordinary acid soil. The initial acidity of these green manures is thus shown to be several times that of an equal bulk of ordinary acid soil. In the process of decomposition, however, green manures, like the leaves already described, tend to pass from an acid to an alkaline state, but at rates which have not yet been determined.

The lime requirement of green manures as given in Table III must not be understood as the amount of lime actually required to neutralize the acidity of a crop of these plants when plowed under. A compact 6-inch layer of green manure would never be used in actual practice, but a much smaller amount, as estimated in Table IV. This table gives the estimated weight of the dry crop per acre, roots as well as tops; the amount of lime in the crop, expressed in terms of ground limestone; and the acidity, in terms of the additional amount of ground limestone required to neutralize the initial acidity.

TABLE IV.—*Weight, lime content, and acidity of green manures to the acre.*

Crop.	Weight.	Lime content.	Acidity, expressed as lime requirement.
	Tons.	*Pounds.*	*Pounds.*
Alfalfa	2½	139	267
Red clover	2	131	142
Cowpea	2½	92	200
Rye	2	11	178
Broom sedge	1	4	89

INJURIOUS EFFECTS OF ACIDITY.

Although science can not be said to have demonstrated the full details of the various ways in which ordinary crops are injured by soil acidity, there is known to be one important chemical process which is suspended under acid conditions, namely, the transformation of "unavailable" nitrogen into the form of nitrates. The nitrifying bacteria do not thrive in acid media. In consequence, those crops that require their nitrogen in the form of nitrates suffer

from nitrogen starvation when growing in acid humus. For such crops the neutralization of the acidity by lime is of vital importance, for not until this is done can the nitrogen of the humus, however abundant, be changed into nitrates. Whatever other direct injurious effect acidity may have on crops, the fact that it checks the nitrification of humus is of itself sufficiently important and significant to justify all the investigation that the subject has received.

SOURCE OF NITROGEN FOR ACID-LAND PLANTS.

There is another phase of the acidity question. Many plants thrive in soils which are acid and which therefore theoretically can produce no nitrates. There are three possible methods by which these plants may secure their nitrogen:

(1) Although a sample of soil when tested as a whole shows an acid reaction, there may exist in it innumerable minute tracts, surrounding particles of lime, where the reaction is alkaline and where nitrates are in process of manufacture. It is to be hoped that investigators will find some means to determine the possibility of such a method of nitrogen nutrition in acid soils.

(2) Many acid soils contain a large amount of nitrogen in the form of ammonia, and while hitherto scientific opinion has been much divided over the question whether ordinary crop plants can utilize ammonia nitrogen directly, without transformation by bacteria into nitrates, careful chemical investigation under such conditions as to eliminate the possibility of bacterial action should enable us to determine which of our crop plants can feed on ammonia nitrogen and which can not. Intelligent agriculture needs this information.

(3) It is conceivable that a crop plant might utilize nitrogen that existed in organic form in the humus of the soil, having not yet reached the ammonia stage of decomposition. It is agreed by plant physiologists that ordinary plants, those bearing green foliage, are unable to do this. It is also agreed by plant physiologists that fungi not only can but habitually do use organic nitrogen. These two facts warrant the consideration of a remarkable partnership that exists between certain leaf-bearing plants and certain fungi, a partnership the significance of which has only recently begun to be appreciated by botanists and is almost unknown in agricultural literature.

The subject is well illustrated in the blueberry. The possibility of the culture of this wild berry has been under investigation for several years, the experiments having now reached a successful conclusion.[1]

[1] Experiments in Blueberry Culture, United States Department of Agriculture, Bureau of Plant Industry, Bulletin 193, 1910; also Directions for Blueberry Culture, United States Department of Agriculture, Bureau of Plant Industry, Circular 122, pages 3 to 11, 1913.

THE MYCORHIZAL FUNGI.

It has been found that the blueberry requires an acid soil, that it grows luxuriantly in a mixture of peat and sand containing nitrates in extremely minute quantities, if, indeed, they are present at all. The plant bears upon its roots a fungus the microscopic threads of which lie partly on the outside of the root, but penetrate also into the living interior. While the experimental results can not as yet be regarded as furnishing an absolute proof, the evidence strongly indicates that the fungus takes up organic nitrogen from the abundant supply existing in the peat and delivers it to the plant in some available form.

These mycorhizal fungi exist on the roots of many wild plants inhabiting acid peat. The extent to which they occur on the roots of cultivated plants that grow in acid soil is not yet known. It can hardly be doubted, however, that many such plants will ultimately be found to take their nitrogen through these fungi. Other acid-land plants will doubtless be found to possess the ability to use nitrogen in the form of ammonia without the help of fungi.

This outline of the probable means of nitrogen assimilation in acid-land plants prepares the way for the following survey of crops adapted to acid soils.

CROPS ADAPTED TO ACID SOILS.

BLUEBERRY.

The blueberry, to which allusion has already been made, gives every indication of adaptability to commercial culture, now that its soil requirements and its peculiarities of nutrition are known. The establishment of a blueberry-growing industry will mean the utilization of sandy, acid lands in the pine barrens of New Jersey and similar situations now regarded as almost useless agriculturally.

CRANBERRY.

The cranberry is an acid-land fruit. It has a root fungus similar to that of the blueberry and doubtless of the same importance to the welfare of the plant. The lands used for cranberry culture are of a special kind, with such an excess of moisture and acidity that in comparatively few instances would they have been used for any other agricultural purpose.

STRAWBERRY.

The strawberry is now coming to be recognized as a plant that thrives as well, if not a little better, in soils having an acid reaction. The grower who appreciates this characteristic of the strawberry is relieved of the expense of applying lime to his land unless required by other plants in his crop rotation.

BLACKBERRY, RASPBERRY, AND BLACKCAP.

The blackberry, the American red raspberry, and the blackcap are found wild in acid soils and all thrive in cultivation in such land if the ground is well supplied with humus.

POTATO.

The potato has long been recognized as yielding especially well when grown on a newly turned sod or on newly cleared land, conditions which are now recognized as productive of acidity as well as a later increase of humus. The potato, moreover, furnishes one phenomenon of special interest to acid-land agriculture. The potato scab, a disease which reduces the size of the tubers, injures their appearance, and lessens their value, is controlled without difficulty if the soil reaction is acid. The disease is caused by a fungus known as *Oospora scabies*, the growth of which is inhibited by acidity.

SWEET POTATO.

The sweet potato, the cultivation of which extends as far north as New Jersey, yields heavily in acid soils. In the South it is the standard vegetable on such lands.

RYE.

Rye is a cereal that grows almost as well on acid as on nonacid soils. It is the characteristic grain on the reclaimed acid heather lands of northern Europe. In the United States it is found particularly useful as a cover crop on areas subject to washing in winter, whether the rye is later cut for hay, or plowed under for green manure, or harvested for its grain.

OATS.

As a grain for spring sowing, oats do well in acid soils, though this crop is not so acid tolerant as millet. It is often useful in rotations where the crop of the preceding summer can not be harvested early enough to permit the successful sowing of a winter cover crop like rye.

MILLET.

The different varieties of foxtail millet, including common millet, German millet, and Hungarian millet, are strongly acid tolerant. As they are also drought resistant and reach maturity in a remarkably short period, they are useful for summer sowing in land temporarily vacant between the more important crops of a rotation.

BUCKWHEAT.

Buckwheat is well known as a pioneer crop on newly cleared timberland. Its reputation also as a crop for worn-out lands is another

indication of its resistance to acidity, for such lands are usually acid. If, however, the mineral food is actually insufficient and there is no humus from which nitrogen can be extracted, one can not reasonably expect a heavy yield, even from buckwheat. The plant can withstand acidity, but not starvation besides. A reasonable amount of humus, such as is easily provided by plowing under a good leguminous crop, will ordinarily result in heavy yields of buckwheat.

REDTOP.

The principal grasses of ordinary agriculture, notably bluegrass and timothy, do poorly in acid land. To this general rule, however, there is one notable exception, redtop. This grass often reaches a luxuriant development in markedly acid lands. The stem growth of redtop, however, is so light compared with that of timothy that it is not recommended as a substitute so far as the production of hay is concerned, but, like bluegrass, its bottom growth is heavy and it makes an excellent pasture.

CORN.

Corn yields well under acid conditions if the soil is well provided with humus and the usual mineral nutrients. It may be regarded as a plant having a fair degree of acid tolerance.

CARROT.

The carrot, as might readily be inferred from its common occurrence as a weed in old and worn-out fields, is decidedly tolerant of acidity. It grows almost equally well in either type of soil.

TURNIP.

The common turnip produces good though probably not maximum yields on acid land, differing in this respect from the rutabaga, or Swedish turnip, which yields well only in neutral or alkaline soils.

LEGUMINOUS PLANTS FOR ACID SOILS.

While the crop plants thus far enumerated furnish material for such agricultural necessities as grain, grain hay, fodder, root crops, cover crops, pasturage, and small fruits, they do not supply the nitrogenous green manures which are necessary to the maintenance of soil fertility under most agricultural conditions and which are satisfactorily derived only from leguminous plants. It is admitted that in acid-land agriculture red clover, the ordinary green-manure crop, is not available for this purpose. What, then, are the leguminous plants which will produce in an acid soil a heavy growth of tops equal in value to red clover for plowing under as green manure? The answer is, cowpea and hairy vetch. Crimson clover, soy bean, lupine, and serradella are also useful under certain conditions.

COWPEA.

For a century the cowpea, of many varieties, has been the chief leguminous crop of the Southern States, grown for hay, for its edible seeds, and as a green manure. Only recently has its resistance to acidity been recognized. The experiment stations have carried the plant much farther north in the past few years, until now some of the varieties are in successful cultivation in Massachusetts, New York, and Michigan. Sometimes the yield of tops is so dense and heavy that only by the use of special attachments to the plow can the crop be turned under.

SOY BEAN.

The soy bean is of much more recent introduction into the United States than the cowpea. In its tolerance of acidity the soy bean probably equals the cowpea, and it has two points of superiority. It grows farther north and its yield of seed is much greater, often being as high as 30 bushels per acre. Some of the varieties have been grown with success as far north as New Hampshire, Ontario, and Wisconsin. The seed of the soy bean has one remarkable characteristic. It contains no starch, but about 35 per cent of nitrogenous matter. Such a composition ought to give these beans a special value in rations for cattle. Within the climatic limits of its profitable cultivation this plant may prove to be exceedingly valuable on the acid dairy farms of New England, where enormous sums are spent for the purchase of southern and western nitrogenous cattle feeds.

HAIRY VETCH.

Hairy vetch differs in one conspicuous feature from the cowpea and soy bean. Both these plants are sown in the spring or early summer and mature and die in the fall of the same year, but the hairy vetch is what is known as a winter annual. It is sown in late summer, germinates at once, passes the winter as a small plant, makes a heavy growth in the following spring, and matures its seed in early summer. It so closely accords in season with rye that the two form an ideal mixture when the rye is to be plowed under for green manure or cut for early hay.

CRIMSON CLOVER.

Crimson clover is a leguminous plant that does well in sandy soils from New Jersey southward. It appears to be tolerant of acidity and may come to be definitely recognized as a plant of this class. The seed is sown in late summer, becomes well established before winter, makes a luxuriant growth in early spring, and is ready for the scythe or the plow in May.

Further experimentation will doubtless result in important additions to this list. It is especially desirable that additional leguminous plants be found that are hardy far north and otherwise satisfactory in rotations. Lupine and serradella, both much employed in the great potato-growing districts of Pomerania and other portions of north Germany, ought to be useful in this country, but thus far they have not found favor, perhaps because of the poisonous qualities of lupine and the rather light yield of serradella.

ACID-TOLERANT CROPS IN ROTATION.

From the data already given, the farmer who desires to try an experiment in acid-land agriculture will be able to select the crops that will give him the rotation suited to the requirements of the particular kind of agriculture in which he is engaged. Some of these crop plants are comparatively new and require special handling as to the best time and manner of sowing. When grown for the first time the leguminous plants require soil inoculation with the special bacteria of their root tubercles.

Rotations made up from the acid-tolerant crops described above have been very successful on some of the sandy, acid farms in Maryland, a few miles northeast of Washington.

The trees in one newly planted orchard of Grimes Golden apples have been kept in a remarkable condition of growth by one initial application of manure in the year of their planting, succeeded by the following rotation: In May the ground is sowed to cowpeas. These are plowed under in September and followed immediately by the sowing of rye mixed with hairy vetch. In the following May the mixed crop is plowed under. The same one-year rotation has been followed year after year. Under this treatment the soil, which has the appearance of almost pure sand, has become so fertile without the application of lime, commercial fertilizer, or manure that an occasional crop of cowpeas has been cut for hay without serious interference with the progress of the orchard.

Another successful combination is a one-year rotation of corn and crimson clover by which a heavy yield of corn is produced every year without lime or fertilizer in a soil that looks almost like beach sand. The land, which is gently sloping, is ridged in contours at each interval of 2 feet in elevation, the corn rows being parallel to the contour next above them. The crop of crimson clover with the corn stubble is plowed under in April a little before corn-planting time. In August after the last cultivation of the corn the crimson clover is sown between the rows. The seeds germinate so readily that when broadcasted a light shower will start them off. If dry weather follows before they have had time to send their roots deep

enough to reach the permanently moist soil beneath the dry surface layer, the young plants promptly die. It is safer, therefore, either to sow the seed with a drill or to broadcast it during a heavy rain, which will beat the seed into the ground and at the same time furnish sufficient moisture to carry the young plants through the period of danger from drought.

The turning under of heavy leguminous crops on these sandy soils restocks the land with humus and the humus decomposes to such a stage that a condition of partial or temporary alkalinity appears at times to have been reached, for good crops of even such nonacid plants as wheat and timothy are sometimes secured from these naturally acid lands after the treatment here described.

BENEFICIAL EFFECTS OF SOIL ACIDITY.

An actual beneficial effect from soil acidity is likely to be felt in another direction hitherto insufficiently recognized, namely, the control of some of the fungous diseases of cultivated plants. Reference has already been made (p. 8) to the fact that the fungus causing the scab of the potato can not grow if the soil reaction is acid. Another example is furnished by the root-rot of the tobacco plant, caused by a fungus named *Thielavia basicola*. Briggs has shown that this disease is prevalent in tobacco plantations that have received excessive applications of lime or other alkaline fertilizers and that it is readily controlled by the use of acid fertilizers.

In Porto Rico the extension of the pineapple industry has been retarded by a disease known as chlorosis, the principal external mark of which is the yellowing of the foliage and the consequent poor nutrition of the plant. From investigations by Gile and by Loew it appears that the yellow color of the leaves and the accompanying weakness of the plant are due to the lack of iron, and that where the soil contains an excess of lime the organic acids which are needed to dissolve the iron of the soil are themselves neutralized and the iron, although present, is not available for absorption by the pineapple roots.

In the upbuilding of the agriculture of the arid Western States certain diseases of plants have appeared which are commonly called by plant physiologists cases of "malnutrition." The causes of these maladies are unknown. The maladies themselves, however, are associated with pronounced alkalinity of the soil and they occur in plants that were native in humid regions where the soil varies from weak alkalinity to actual acidity. May it not be worth while for investigators to ascertain whether some of these mysterious "malnutrition" difficulties can not be remedied by an acid treatment of the soil?

There is one other feature of the acid-soil question which merits the serious consideration of agriculturists. Recent investigators have shown that various fungi are able to fix and feed upon the nitrogen of the atmosphere, just as do the bacteria of the clover root tubercles and certain free bacteria of alkaline and neutral soils. One Swiss investigator, Charlotte Ternetz, has isolated from acid soils several fungi in which this faculty not only occurs but is developed to a high degree of efficiency. It has not yet been fully demonstrated that true mycorhizal fungi possess this faculty of nitrogen fixation, but there is much evidence that they do. Should this become definitely established, agriculture must recognize in the mycorhizal fungi a direct and powerful means of adding to the store of available nitrogen, and the culture of mycorhizal plants in acid soils will have a significance far beyond the mere value of the crops produced by them.

CONCLUSION.

In closing this paper the writer desires to impress on agricultural investigators (1) that soil acidity is not always an objectionable condition which invariably requires an application of lime, (2) that under certain economic conditions a complete system of acid-land agriculture is practicable and desirable, and (3) that the extent to which our cheap eastern acid lands can be utilized with small applications of lime, or under some conditions without its use, is a legitimate and important subject for detailed investigation, from which may reasonably be expected results of far-reaching economic importance.

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AGRICULTURAL TRAINING COURSES FOR EMPLOYED TEACHERS

With a Suggested Reading Course in Agriculture Based on Farmers' Bulletins.

By Edwin R. Jackson,
Assistant in Agricultural Education.

INTRODUCTION.

Perhaps the most noteworthy feature in the educational progress of the Nation during recent years has been the development of agricultural education, particularly in the public schools. From May, 1910, to March, 1912, the total number of institutions giving courses in agriculture increased from 863 to 2,575, or at the rate of more than 76 each month; and this increase is found almost entirely in schools of the secondary grade. This does not take into account the vast number of elementary and rural schools into which some instruction in agriculture has been introduced of which no definite record is obtainable, but of which there must be an enormous number, since in at least 19 States agriculture is required by law to be taught in the common schools.[1]

It is altogether probable that the spread of agricultural instruction would have been even more rapid had it not been for the difficulty which has been encountered in procuring teachers able to give instruction in the subject. Responding to the demand for teachers of agriculture, the normal schools are very generally introducing courses in agriculture, while many of the agricultural colleges, on the other hand, are offering special courses for teachers. This has resulted in providing a limited number of trained teachers—hardly enough, however, to supply the needs of the secondary schools and special schools of agriculture. Few, indeed, of the normal or college trained teachers find employment in the rural common schools.

[1] The States in which agriculture is required to be taught either in all common schools or at least in rural schools are Alabama, Arkansas, Georgia, Iowa, Louisiana, Mississippi, Missouri, North Carolina, North Dakota, Oklahoma, Ohio, Oregon, South Carolina, South Dakota, Tennessee, Texas, Washington, West Virginia, and Wisconsin. In some of these States the subject is not required by legislative act, but is put into the required course of study prescribed by the State superintendent of public instruction pursuant to authority of law. In addition to these, Idaho, Pennsylvania, and Utah require agriculture taught in all rural high schools.

The result is that while there has been a widespread demand for the teaching of agriculture in the rural schools, the teachers who are found in these schools are generally poorly equipped to give such instruction.

Added to the urgent demand from the schools themselves that teachers should have training in agriculture, there has been the spur of legislation in some 19 States in which an examination in agriculture is now one of the prerequisites for obtaining a teachers' certificate.[1]

Thus it will be seen that one of the most urgent things which now needs to be done in order to promote the development of agricultural education is to provide better means of training teachers in agriculture. This need is especially urgent in the case of teachers already in service in elementary schools. The widespread movement toward the development of teacher-training courses in high schools and the parallel growth of agricultural courses in these schools will undoubtedly result in a few years in producing teachers for the common schools who have had considerably more training, both professionally and in scientific agriculture, than those now in service. The immediate need, therefore, seems to be to provide means by which teachers now engaged in regular school work, who have not had the opportunity to study agriculture, and who can not afford to take a year or more away from their employment in order to pursue a course of study at an agricultural school, may still receive a working knowledge of the subject in order to keep abreast of the times, as well as to comply with the requirements of the law in those States where agriculture must be taught.

With a view to ascertaining just what means are now open to employed teachers, by which they may acquire agricultural training and at the same time continue in service, this office has undertaken an investigation of the subject among the educational institutions of the country, and the report of this investigation is included in this bulletin.

MEANS BY WHICH EMPLOYED TEACHERS MAY ACQUIRE AGRICULTURAL TRAINING.

SUMMER COURSES.

Without doubt the most popular as well as the most efficient means of giving training to employed teachers are the summer courses offered by the colleges and normal schools, and a large proportion of these include more or less complete courses in agriculture. Since these summer sessions are almost without exception intended specifically for the benefit of teachers, it follows that in the majority of

[1] These States are: Alabama, Arkansas, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, Nebraska, North Carolina, North Dakota (optional), Ohio, Oklahoma, South Carolina (may be required for county certificates), Tennessee, Texas, Virginia (optional), West Virginia, and Wisconsin.

cases courses are presented which aim to help teachers in elementary and secondary schools in the teaching of agriculture, particular attention being given to the pedagogy of the subject.

Most of the summer sessions continue for at least six weeks. Some are in session for as long as 10 or even 12 weeks. In some it is possible for the student of agriculture who wishes to specialize in that subject to have two lessons each day in agriculture, thus completing in 6 weeks, for example, what amounts to 12 weeks' work. In most of the institutions of college grade college credit is allowed for work done at the summer session. In two or three institutions the regular school session continues throughout the summer, the faculty, equipment, and methods of the summer quarter being the same as during any other term of the school year. For the teacher who cares to sacrifice the possible pleasures of the vacation period for the opportunity of self-improvement, and who can afford the expense, the advantages of the summer school over any form of nonresident study are obvious. The instruction is usually of a high class; there are the inspiration and enthusiasm which come from association with others interested in the same line of work; and there are usually adequate equipment and apparatus for laboratory and field work, since the sessions are held at some established college or normal school, so that its entire plant is available to the summer students.

The following is a list of institutions maintaining summer courses in agriculture:

List of institutions maintaining courses in agriculture in summer sessions.

State.	Institution.	Location.	Nature of course offered.
Alabama	Agricultural and Mechanical College for Negroes.	Normal	El. agr. for teachers.
	Alabama Polytechnic Institute.	Auburn	El. agr., teaching agr., and gardening.
	Howard College	Eastlake	
	Tuskegee Institute (colored)	Tuskegee Institute.	Several courses in gen. agr.
	University of Alabama	University	El. and sec. agr., biological nat. study, 6 wks.
Arkansas	State Normal	Conway	El. agr.
California	State Normal School	San Diego	El. agr., methods of agr. instr., 6 wks.
	University of California	Berkeley	El. and sec. agr.; also grad. work. Several special courses for teachers, 6 wks.
Colorado	Colorado Agricultural College	Fort Collins	Gen. agr. and gardening, 6 wks.
	Denver Normal School	Denver	El. and sec. agr., 6 wks.
Connecticut	Agricultural College	Storrs	Nature study and agr. for teachers, 4 wks.
Florida	Normal Institute	Madison	El. agr.
	Rollins College	Winter Park	
Georgia	University of Georgia	Athens	Nature study, el. and sec. agr., 5 wks.
Idaho	Lewiston State Normal School.	Lewiston	El. agr. and gardening.
	State Normal School	Albion	Agr. for teachers.
	University of Idaho	Moscow	Agr. for teachers in el. and sec. schools, 6 wks.
Illinois	Northern Illinois State Normal School.	De Kalb	El. agr. and nature study for teachers.
	State Normal University	Normal	Two 6 wk. sessions, el. and sec. agr., agrl. nat. study. A series of 6 courses offered; 2 each year for 3 years.

List of institutions maintaining courses in agriculture in summer sessions—Continued.

State.	Institution.	Location.	Nature of course offered.
Illinois	State University	Urbana	Several courses in gen. agr. and special courses for teachers.
	Western Illinois State Normal School.	Macomb	Agr. for teachers of el. and sec. schools.
Indiana	Central Normal College	Danville	12 wk. course, el. agr.
	Goshen College	Goshen	Several courses for teachers.
	Hanover College	Hanover	Gen. agr. with lab. and field work.
	Muncie Normal Institute	Muncie	Gen. agr. courses.
	Purdue University	La Fayette	Several gen. agr., courses for teachers, 6 wks.
Iowa	State College of Agriculture and Mechanic Arts.	Ames	Several courses, gen. agr. and agrl. pedagogy.
	State Teachers' College	Cedar Falls	El. agr. for teachers, 6 wks.
	Upper Iowa University	Fayette	El. agr. and gardening, agrl. chem.
	Tabor College	Tabor	Lectures in agr., gardening.
	Western Normal College	Shenandoah	El. agr.
Kansas	State Agricultural College	Manhattan	Gen. agr., agr. for rural teachers, 6 wks.
	State Manual Training Normal School.	Pittsburg	El. agr.
	State Normal School	Emporia	Gen. agr., gardening, methods of teaching agr.
	Western State Normal School.	Hays	El. agr. for teachers, 9 wks.
	University of Kansas	Lawrence	Two courses only, sci. basis of agr. and insect life, no gen. agr. offered.
Kentucky	State University	Lexington	Agr. for teachers.
	Western Kentucky State Normal School.	Bowling Green	Nat. study and el. agr., 6 wks.
Louisiana	State Normal School	Natchitoches	School in session throughout the year. Agr. taught in summer quarter, 3 mos. Also special summer normal, 6 wks. for teachers.
	State University	Baton Rouge	Agr. and agr. education, 9 wks.
Maryland	Johns Hopkins University	Baltimore	No gen. agr. but courses nature study as preparation for agr. offered.
	Morgan College (colored)	do	Methods of teaching agr.
Massachusetts	Agricultural College	Amherst	Several courses in agr. and country life for teachers, 4 wks.
	State Normal School	Hyannis	School gard., poultry raising, 4 wks.
Michigan	Northern State Normal School.	Marquette	Agr. for teachers in rural schools.
	State Normal School	Ypsilanti	El. agr., 6 wks.
	University of Michigan	Ann Arbor	Agrl. botany only, 8 wks.
	Western State Normal School.	Kalamazoo	Nature study and agr., 6 wks.
Minnesota	Northwest Agricultural School	Crookston	6 wks. teachers' training school. Courses in el. agr. for teachers.
	State Normal School	Mankato	El. agr. and agr'l. nat. study.
	State Normal School	Moorhead	El. agr., 12 wks.
	State Normal School	Winona	Agr. for teachers.
	State Normal School	St. Cloud	El. agr., 6 wks., two rec. per day.
	University of Minnesota (Agricultural College).	St. Anthony Park.	Several courses, agr. for teachers, and gen. agr.
Mississippi	Mississippi Normal College	Hattiesburg	6 wks. course, el. agr.
	West Central Agricultural School.	Morris	6 wks. teachers' training school. Courses in el. agr. for teachers.
Missouri	Central Wesleyan College	Warrenton	El. agr.
	First District Normal School.	Kirksville	Gen. agr. with field work.
	Missouri Wesleyan	Cameron	Gen. agr. lab. work, 60-day session.
	Missouri Valley College	Marshall	El. agr. with lab. work in summer quarter, for teachers.
	Northwest Normal School	Maryville	Gen. agr.
	State Normal School	Cape Girardeau	Gen. and el. agr.
	University of Missouri	Columbia	Gen. agr.; also special course for teachers, 9 wks.
Nebraska	Nebraska Wesleyan University.	University Place	El. agr.
	State Normal School	Chadron	Two courses for teachers.
	State Normal School	Peru	Gen. agr. during summer quarter. Special course for rural teachers. School continues in regular session during summer quarter.

List of institutions maintaining courses in agriculture in summer sessions—Continued.

State.	Institution.	Location.	Nature of course offered.
Nebraska	State Normal School	Kearney	8 wks. course in agr.
	State Normal School	Wayne	8 wks. agr. for teachers.
	University of Nebraska	Lincoln	8 wks. session. Several courses for high-school teachers.
	York College	York	El. agr., 6 wks.
Nevada	University of Nevada	Reno	6 wks. course.
New Hampshire	Plymouth Normal School	Plymouth	El. agr., nature study, gardening, 8 wks.
New Mexico	New Mexico Normal University.	Las Vegas	El. agr.
New York	Cornell University	Ithaca	Numerous courses in gen. agr. and agr. for teachers.
	Columbia University, Teachers' College.	New York	Gen. agr. with field work, nature study, agr. for teachers, 6 wks.
	New York University	New York	School gardening only.
	Syracuse University	Syracuse	Gen. agr., 6 wks.
North Carolina	East Carolina Teachers' Training School.	Greenville	Agr. for teachers.
	State Normal and Industrial College.	Greensboro	El. agr. and nature study, 8 wks.
	University of North Carolina	Chapel Hill	El. agr., nat. study, gardening.
North Dakota	Agricultural College	Agricultural College.	6 wks. course, agr. for teachers.
	Jamestown College	Jamestown	Agr. for common schools, 6 wks.
	State Normal School	Mayville	El. agr., gardening, 6 wks.
	State Normal School	Valley City	6 wks. course for teachers.
Ohio	Antioch College	Yellow Springs	El. agr.
	Defiance College	Defiance	6 wks. course, el. agr.
	Dennison College	Granville	El. agr., sec. agr. nat. study, methods of teaching agr.
	Lebanon University	Lebanon	Agr. for teachers of rural schools, 8 wks. course.
	Miami University	Oxford	Agr. and nat. study for teachers, 6 wks.
	Muskingum College	New Concord	El. agr., 9 wks.
	Ohio Northern University	Ada	Gen. agr. and gardening, 8 wks.
	Ohio State University	Columbus	Gen. agr. for teachers, 8 wks.
	Otterbein University	Westerville	El. agr., 6 wks.
	State Normal College of Ohio University.	Athens	El. agr. and gardening, 9 wks.
	West Lafayette College	West Lafayette	
	University of Wooster	Wooster	El. and sec. agr., teaching of agr., 8 wks.
Oklahoma	Agricultural and Mechanical College.	Stillwater	6 wks. course for teachers.
	Central Normal School	Edmond	Agr. nat. study; gen. agr., with lab. work.
	East Central State Normal School.	Ada	El. agr., gardening, 10 wks.
	Southwestern State Normal School.	Weatherford	Gen. agr., 10 wks.
Oregon	Agricultural College	Corvallis	El. agr.; methods of teaching agr., 6 wks.
	Oregon Normal School	Monmouth	El. agr., gard., rural sociology.
Pennsylvania	Allegheny College	Meadville	Agr. for teachers.
	Geneva College	Beaver Falls	El. agr., 6 wks.
	Grove City College	Grove City	Agr., hort., agr. chem., 10 wks.
	Juanita College	Huntingdon	El. agr., 6 wks.
	State College	State College	Gen. agr. and gardening, 6 wks.
	State Normal School	Westchester	Agr. for teachers, 6 wks.
South Carolina	Winthrop Normal College	Rock Hill	Agr. and nat. study.
South Dakota	Dakota Wesleyan University.	Mitchell	Agr. with methods of teaching. Rural economics.
	Huron College	Huron	Series of special lectures on agr. during 6 wks. summer term.
	Lutheran Normal School	Sioux Falls	Agr. botany, 6 wks.
	Northern Normal and Industrial School.	Aberdeen	El. agr. Methods of teaching, with special lectures on agr.; 6 wks. session.
	Sioux Falls College	Sioux Falls	El. agr.
	State College	Brookings	Agr. and nat. study.
	State Normal School	Valley City	El. agr., 6 wks.
	Yankton College	Yankton	El. agr. for rural teachers, 6 wks.
Tennessee	East Tennessee State Normal School.	Johnson City	Gen. and el. agr., gardening.
	Lincoln Memorial University.	Cumberland Gap	School in session throughout year. El. agr. taught in summer quarter.
	Morristown Normal and Industrial College.	Morristown	Brief course in el. agr.

List of institutions maintaining courses in agriculture in summer sessions—Continued.

State.	Institution.	Location.	Nature of course offered.
Tennessee	West Tennessee State Normal School.	Memphis	Agr., with lab. and field work.
	University of Tennessee	Knoxville	Gen. agr. and agr. ed., 6 wks.
Texas	Agricultural and Mechanical College.	College Station	6 wks. course for teachers.
	Baylor College	Belton	Agr. for teachers in rural schools.
	Baylor University	Waco	Agr. for teachers, with special lecture.
	Sam Houston Normal Institute.	Huntsville	El. agr., 8 wks.
	University of Texas	Austin	El. and gen. agr., 6 wks.; also agr. ed.
	North Texas State Normal School.	Denton	Agr., 8 wks.
Utah	Agricultural College	Logan	Agr. and nat. study, 6 wks.
Vermont	University of Vermont	Burlington	Agr. for teachers, 6 wks.
Virginia	Emory and Henry College	Emory	El. agr.
	College of William and Mary	Williamsburg	(Summer session held at Dublin, Va.). El. agr., 8 wks.
	St. Paul Normal and Industrial School (colored).	Lawrenceville	One month, el. agr., with practical farm work.
	State Female Normal School	Farmville	Agr. and nat. study.
	State Normal and Industrial School for Women.	Harrisonburg	Nat. study, gard., el. agr. Two sessions, 6 and 4 wks., respectively.
	State Summer School	Fredericksburg	El. agr., 4 wks.
	University of Virginia	Charlottesville	Gen. agr., nat. stud., gard., 6 wks.
	Virginia Normal and Industrial Institute (colored).	Petersburg	El. agr., nat. stud., gard., 6 wks.
	Virginia Union University (colored).	Richmond	El. agr., 6 wks.
Washington	State College	Pullman	Gen. agr.; methods of teaching agr., 6 wks.
	State Normal School	Bellingham	El. agr., 9 wks.
	State Normal School	Cheney	El. and gen. agr., gardening, 9 wks.
	State Normal School	Ellensburg	Agr., nat. study, gard.
	University of Washington	Seattle	Gen. agr., hort., gardening.
West Virginia	Davis and Elkins College	Elkins	El. agr.
	Fairmont State Normal School	Fairmont	El. agr.
	West Virginia University	Morgantown	El. and gen. agr., 9 wks.
Wisconsin	Outagamie County Training School.	South Kaukauna	El. agr. for teachers; also lab. course, 6 wks. session.
	River Falls State Normal School.	River Falls	El. agr., 8 wks.
	State Normal School	La Crosse	Agr., 6 wks.
	State Normal School	Oshkosh	Agr., 6 wks.
	State Normal School	Superior	El. agr., 6 wks.
	State Normal School	Whitewater	El. agr. for teachers.
	University of Wisconsin	Madison	Grad. and undergrad. work in gen. agr. Courses for teachers of rural and sec. schools.
	Waupaca County Normal School.	New London	El. agr. for teachers.
Wyoming	University of Wyoming	Laramie	Gen. agr., 6 wks.

SPECIAL SHORT OR EXTENSION COURSES.

An effort on the part of some of the colleges and normal schools to give special facilities for the training of employed teachers in the subject of agriculture is shown by the fact that in a number of instances special short courses in agriculture are offered during the regular school session, usually in the spring term and lasting through the months of April and May. Thus, the Agricultural and Mechanical College of North Carolina holds a special "May school" for teachers at which agriculture is taught. Some of the schools continue their sessions into June for the benefit of teachers whose schools close early in the spring. Harvard University offers special work

for graduate students in a term lasting from February to November, provision being made, however, for students to work during the summer only, if desired. A bachelor's degree is required for admission to this work. Columbia University offers to employed teachers the advantages of afternoon, evening, and Saturday classes during the regular school year, and agriculture is one of the subjects thus taught. Afternoon and Saturday classes in agriculture for teachers are also offered in the Fresno State Normal School, Fresno, Cal.

Agriculture has come in recent years to hold a prominent place on the programs of teachers' institutes. However, these institutes are generally in session only one or two weeks at the most, hence the instruction given there must necessarily be more or less cursory and superficial. Nevertheless, these institutes have doubtless been of much influence in arousing the interest of teachers in the subject of agriculture and in the inspiration they have given to teachers to become better prepared. The plans on which institutes are held vary greatly in the different States, and in many States they are being gradually superseded either by brief inspirational teachers' meetings on the one hand, or on the other hand by summer normals, in which the teachers of a number of counties meet together at some central location, often at some college or other institution in connection with the ordinary summer school. This plan is followed, for example, in Virginia and in South Dakota. At Aberdeen, S. Dak., 10 counties will hold their joint institute a period of one week in connection with the summer school of the Northern Normal and Industrial School. A very promising plan, devised by Garland A. Bricker, of the Ohio State University, has been successfully put into operation by him in Ohio. This plan is to organize and conduct special extension schools for teachers in various counties in the State, these schools being in charge of instructors furnished by the extension staff of the State agricultural college. The funds necessary to carry on these extension schools are, according to a ruling of the Attorney General of the United States, available to the land-grant colleges under a proviso of the Nelson Amendment (34 Stat. L., 1256, 1281), approved March 4, 1907, by which a portion of the funds appropriated by this act from the Federal Treasury for the use of these colleges may be used "for providing courses for the special preparation of instructors for teaching the elements of agriculture and the mechanic arts."

Prof. Bricker's plan is to organize a teachers' extension school in cooperation with the local school authorities whenever a sufficient number of teachers in one locality have signified their desire to enroll and take the course, on much the same plan as that followed by many agricultural colleges in conducting farmers' short courses. To cover local expenses a small fee is charged each teacher who

enrolls. Prof. Bricker's plan is to hold the sessions of the school on Saturdays, either of consecutive or alternate weeks, the session continuing for six Saturdays. There would seem to be no reason why a similar teachers' short course might not be conducted continuously for a week or two weeks in connection with the teachers' institute, or the short course made a substitute for the regular institute or elective therefor at the option of the teacher.

The following is a list of institutions offering short or extension courses in agriculture for teachers:

List of institutions offering special short courses or extension courses in agriculture for teachers.

State.	Institution.	Location.	Nature of course.
California	Fresno State Normal School	Fresno	Evening and Saturday classes in agriculture for teachers.
Indiana	Moores Hill College	Moores Hill	Special teachers' course during spring term.
	Vincennes University	Vincennes	Do.
Kansas	State Agricultural College	Manhattan	Special courses during spring term for rural and high-school teachers.
Massachusetts	Harvard University (Graduate School of Applied Science).	Cambridge	Term from February to November. Graduate work in entomology and applied biology. No work in agriculture, as such, offered. Students may take summer work only.
Michigan	Gratiot County Normal	Ithaca	Ten weeks' course in elementary agriculture offered in spring term.
Mississippi	Agricultural and Mechanical College.	Agricultural College.	Short course for teachers during spring term.
	Industrial Institute and College.	Columbus	Two terms of six weeks each in spring, with special course for teachers.
New York	Columbia University	New York	Afternoon and Saturday classes in agriculture. Lecture and laboratory work.
North Carolina	Agricultural and Mechanical College.	West Raleigh	Special "May school" for teachers, with courses in agriculture and gardening.
Ohio	State University	Columbus	Special extension schools in agriculture for teachers, at various points in State. Held on Saturdays.
Pennsylvania	Central State Normal	Lock Haven	Seven weeks' course in agriculture and nature study in spring term, for teachers.
	Clarion State Normal	Clarion	Course in agriculture and nature study in spring term, for teachers.
	Millersville State Normal	Millersville	Course in agriculture and nature study during spring term, for teachers.
West Virginia	State Normal School	Glenville	Elementary agriculture during spring term.
Wisconsin	Oneida County Teachers' Training School.	Rhinelander	School continues in session until last of June for benefit of teachers. Agriculture offered in spring term.

CORRESPONDENCE COURSES.

The study of agriculture by correspondence has grown rapidly in favor in the last few years, and this method of study has many advantages which adapt it specially to the needs of employed teachers. Probably chief among these advantages is the fact that by this plan the work can be taken up and pursued at the convenience of the

student without any interruption of his regular employment and without taking up the greater part of the vacation period. The expense incident to a correspondence course is usually small. Another advantage lies in the fact that correspondence work can be carried on by single individuals, and the student is not required, therefore, to attend upon the sessions of any institution, thus saving money, time, and travel. It is undoubtedly true that under the guidance of a good correspondence course much more systematic and thorough work can be done than if the student depends upon mere general reading.

On the other hand, correspondence study undoubtedly has many disadvantages. It is hardly possible for the student to do more than an elementary grade of work by this method, and there is considerable danger of his getting incorrect ideas on the more complex questions which arise, because of the absence of any one to question him and to correct his inaccurate impressions. Furthermore, there is a lack of enthusiasm in isolated study which is generally found when several students are associated together. No one can hope to learn as much or as readily by the correspondence method as when associated with other students in a class under the direct supervision of a competent instructor. The personality of such an instructor is a great factor in class instruction, which is wholly lacking in correspondence work. Another great disadvantage of correspondence work lies in the practical impossibility of doing thorough laboratory or experimental work. Some simple experiments which do not require any apparatus, or only such equipment as may be constructed at home, may, of course, be performed; and some field observations and experiments may be conducted if the student is industrious and conscientious enough, but at best the work of this sort must be more or less crude and unsatisfactory.

The popular demand for correspondence courses in agriculture is evidenced by the number of State and private institutions in which such courses are now offered. The results of a recent investigation by this office show that at present there are in the United States and its territories, as nearly as can be learned, 25 State institutions and 5 private schools in which some regularly established correspondence work in agriculture may be done. Besides, there are five private correspondence schools which offer more or less complete courses in agriculture. In at least seven of the State schools college credit may be obtained by students having the proper qualifications upon passing satisfactory examinations. In one, credit may be prescribed by the State superintendent of public instruction. In several others certificates are awarded for the successful completion of a certain number of courses. The number of distinct courses in agriculture offered by these various institutions ranges from 1 to 56. Nearly all these institutions offer courses in elementary agriculture or agricultural

pedagogy which are adapted especially for teachers in rural and elementary schools. Many of the courses in the State institutions are free to residents of the State except for the cost of necessary textbooks and postage charges. Others of the State schools charge small fees, the highest being $5 per course. The tuition charges in the private correspondence schools are generally about $20 to $25 for the complete courses, and frequently the necessary textbooks are furnished.

The plan of work in the correspondence courses is in general the same. Certain parts of the textbooks or bulletins are assigned to be studied, and when these have been read the student is required either to outline the contents of the assignment or to fill out certain question blanks as a kind of examination on the lesson. These written outlines or reports are then mailed to the school, where mistakes are checked up and corrected either by letter or by marking on the report references to the page of the text where the correct statement is found, the corrected report being then returned to the student. In a few instances the student is required to perform simple experiments in addition to the textbook studies.

Below is a list of institutions from which correspondence instruction in agriculture may now be obtained. Most of the State schools accept for enrollment nonresident students, though in several instances the fees are higher for persons not residing in the home States.

Correspondence courses in agriculture.

[In public and private colleges and normal schools.

State.	Institution.	Location.	Person in charge.	Number of courses.	Cost.	Credit given.	Nature of work.	Remarks.
Arkansas	University of Arkansas.	Fayetteville	Prof. J. M. Wilson	10	Free, except books and postage.	No credit	Studies of texts and bulletins.	Course I, elementary agriculture specially for teachers.
California	University of California.	Berkeley	Dean Thomas F. Hunt.	.....	No fees	do	Studies of texts, bulletins, and prepared lessons.	Several courses offered. Courses for teachers in preparation.
Florida	University of Florida	Gainesville	Dean J. J. Vernon	14	$1 registration and cost of supplies.	do	Studies of texts, etc.; experiments.	Course I, elementary agriculture specially for teachers.
Do	Agricultural and Mechanical College for Negroes.	Tallahassee	Pres. N. B. Young	1	No fees	do	Study of texts	Course is for teachers.
Idaho	State Normal School	Albion	Pres. G. A. Axline	1	$5 enrollment fee	Credit on normal course.	Study of text; reference reading.	Elementary agriculture and gardening for teachers.
Iowa	Western Normal College.	Shenandoah	Pres. J. M. Hussey	1	$15 for full course	Credit on college course.	Study of texts	Intended for teachers.
Kansas	State Agricultural College.	Manhattan	Prof. H. L. Kent	56	From $1 to $4 per course.	College credit under certain conditions.	Studies of texts and bulletins.	Course A I, elementary agriculture, adapted for teachers.
Do	Highland College	Highland	Pres. W. C. T. Adams	1	$10 for full course	Credit on college course.	do	Elementary agriculture for teachers.
Do	State Manual Training Normal School.	Pittsburg	Prin. Geo. E. Myers.	4	.....	No credit	Lesson outlines, with reference readings from texts and bulletins.	Course I is in elementary agriculture, suited to teachers.
Maine	University of Maine.	Orono	Dean L. S. Merrill	11	Free, except supplies.	No credit toward degree.	Studies of texts, etc.	
Massachusetts	Agricultural College.	Amherst	Prof. W. D. Hurd	16	$1 per course, plus cost of supplies.	No credit	Prepared lessons; texts for collateral reading.	Course 10, "Agriculture in common schools," and Course II "Agricultural Education" especially for teachers.
Mississippi	Agricultural and Mechanical College.	Agricultural College.	Prof. J. K. Morrison	1	No fees	do	Bulletins prepared by college.	Course intended for poultry clubs.
Do	Normal College	Hattiesburg	Prof. T. F. Jackson	1	$2 enrollment fee	Credit allowed on normal course.	Outlines for studies of texts and bulletins.	Course intended for rural teachers.
Missouri	University of Missouri.	Columbia	Secy. S. D. Groner	14	$3.50 per credit-hour; bulletins free.	Credit on two-year course.	Study of bulletins	Intended for farmers, but open to teachers.

Correspondence courses in agriculture—Continued.

State.	Institution.	Location.	Person in charge.	Number of courses.	Cost.	Credit given.	Nature of work.	Remarks.
Nebraska	University of Nebraska.	Lincoln	Prof. A. A. Reed	3	$5 per course, cost of texts extra.	College credit may be obtained.	Study of texts, etc.	Two courses for high-school teachers; one for rural teachers.
New Mexico	College of Agriculture and Mechanic Arts.	State College	J. O. Miller, registrar.	3	$1 to cover postage; texts to be purchased.	No credit	do	Course I, agricultur for teachers.
Oregon	Agricultural College.	Corvallis	Prof. R. D. Hetzel	3	$1 enrollment plus cost of books, etc.	do	Study of texts	
Pennsylvania	State College	State College	Prof. Thos. I. Mairs	35	Cost of supplies only.	No credit toward degree.	Study of texts, etc.	Course 73, pedagogy of agriculture.
South Carolina	Agricultural (Clemson College).	Clemson College.	Prof. W. W. Long	4	$1 enrollment to cover postage.	No credit	do	All courses intended for teachers.
South Dakota	Agricultural and Mechanical College.	Brookings	Prof. A. A. Brigham	30	From $0.50 to $1 per course, plus supplies.	do	do	Course D, teachers course.
Do	State Normal	Madison	Prof. L. G. Atherton	4	No charge except cost of texts.	Prescribed by State superintendent.	Studies of texts, etc., with experiments.	All courses intended for teachers.
Texas	Agricultural and Mechanical College.	College Station	Prof. O. H. Sellers	20	From $0.50 to $3.50 per course.	No credit except certificate.	Study of texts, bulletins, etc.	Course I, elementary agriculture for teachers.
Utah	Agricultural College.	Logan	Prof. Geo. B. Hendricks.	12	$5 per course	College credit may be obtained.	Study of texts; field and laboratory work.	
Vermont	State Normal	Castleton	Prof. H. K. Farrar	1	$1 enrollment; lesson bulletins furnished free.	None	Special lessons prepared for course.	Course in nature study and agriculture, so arranged that it may be used by teachers in school work as well as studied by the teacher.
Wyoming	University of Wyoming.	Laramie	Prof. T. S. Parsons	2	$5 per course	College credit may be obtained.	Study of texts and bulletins.	

Private correspondence schools.

The following private correspondence schools advertise full courses in agriculture:

American Farmers School, Minneapolis, Minn.
Correspondence College of Agriculture, Fort Wayne, Ind.
Home Correspondence School, Springfield, Mass.
International Correspondence Schools, Scranton, Pa.
Interstate Correspondence School, Chicago, Ill.

READING COURSES.

Several of the State agricultural colleges, while not conducting regular correspondence work in agriculture, offer assistance by means of reading courses to persons wishing to engage in home study. These reading courses are based either upon standard textbooks suggested to the student or upon bulletins issued by the college, in some cases particularly for this purpose. In general, the courses are not intended for teachers but rather for farmers and farmers' wives, although teachers are encouraged to enroll and may derive much benefit from the courses pursued. No credit, so far as can be learned, either toward college degree or certification is allowed for the completion of such courses in any instance.

List of institutions offering reading courses in agriculture.

State.	Institution.	Location.	Nature of course.	Fees.
Arizona	University of Arizona.	Tucson	"Timely Hints for Farmers." Bulletins.	None.
Michigan	Agricultural College.	East Lansing	Based on standard texts. Written reports required.	$1 enrollment for nonresidents.
New Hampshire	New Hampshire College.	Durham	Based on standard texts. Organized for farmers, but open to teachers.	None.
New York	Cornell University, State College of Agriculture.	Ithaca	Special series of bulletins published by college. Questions answered where desired. Two courses—The Farm and The Farm Home.	
Ohio	State University, College of Agriculture.	Columbus	Farmers' reading course based on special series of bulletins.	None.

A SUGGESTED READING COURSE IN AGRICULTURE BASED ON FARMERS' BULLETINS.

The output of agricultural literature in recent years has been prodigious. Numerous farm papers, textbooks, publications of agricultural societies and associations, State and Government publications, all offer opportunity for learning about agriculture. As a rule the information contained in farm papers is more or less scrappy and incomplete, hence it can seldom if ever be used as the basis of systematic study. Textbooks are excellent when they can be obtained, but their cost is considerable, hence the average teacher is as a rule unable to procure more than one or two, if any, and these are generally very elementary in character and often not well selected. Since many of the State and Government publications are technical in character, it is often hard to make a proper selection from this source. In the belief that there are many teachers who would be glad to avail themselves of an opportunity to follow out a thorough course in agricultural reading if one were outlined for them and the necessary text material placed within their reach, the following list of the free publications of the United States Department of Agriculture has been prepared as the basis of such a course.

Unfortunately this list is incomplete in some subjects on which no publications of a popular character are now available. For example, there are few bulletins to be listed dealing with cattle, none with horses, and none of a general nature treating of cotton. Doubtless these and similar deficiencies in this list will be supplied at some time in the future by the department. In the meantime in many of the States bulletins may be obtained from the State agricultural college or experiment station to supplement this list.

With but few exceptions the publications listed are Farmers' Bulletins, since they are generally less technical in character than the bureau circulars and bulletins, and the intention is to select only publications more or less popular in style which may be comprehended easily by the ordinary reader. Even as it is, the Farmers' Bulletins are themselves unsatisfactory in many instances for this kind of use, since they are more adapted for reference purposes than for general reading and study.

On a number of the topics for which publications have been selected and classified in this list additional publications dealing in a more detailed manner with particular phases of the general topic can be obtained if desired. For example, under the subject of "Horticulture—Fruits," there are available in addition to those listed a number of Farmers' Bulletins dealing with particular kinds of fruits, such as strawberries, raspberries, cranberries, and others. Information as to these bulletins may be obtained by reference to the complete list of available Farmers' Bulletins issued by the Division of Publications, United States Department of Agriculture, Washington, D. C.

All the publications listed may be obtained free of cost on application to the United States Department of Agriculture, so long as they are available. Should it happen that any are not available for free distribution when requested they may generally be obtained by purchase from the Superintendent of Documents, Government Printing Office, Washington, D. C. His price for all Farmers' Bulletins and circulars is 5 cents each, but bureau bulletins have various prices, depending upon the cost of publication in each instance.

Perhaps the best method to be followed by the individual reader in using these bulletins as a systematic reading course is to secure the bulletins listed under some single topic, such as "Soils," for example, and thoroughly master all that the publications contain on this subject before going on with the next topic. It will be found very helpful, and a good way to fix important information in the mind as well as to test the reader's understanding of what he has read, if the student prepares an outline of the important points gleaned from the text matter as the reading proceeds. It is important, however, that this outline be made in the reader's own language, avoiding a mere copying of extracts and quotations from the text, since the benefit to be derived from this exercise lies in the possi-

bility it affords of testing the reader's ability to convert the author's thought into such form that it actually becomes his own. Inability to tell in one's own words what has been read is good evidence that the reading has not been done understandingly. The work of selecting the essential thoughts from the text matter and arranging them in a logical outline will help to organize the ideas in the mind of the reader, and to fix them more permanently in his memory, than would be possible if the reading were done without any attempt at picking out and writing down the important facts. Besides, this exercise will act as a sort of brake to safeguard against too rapid and cursory reading.

Where there are several persons in the same locality who wish to pursue the reading course it will be a good plan for them to unite in a reading club, and meet occasionally to quiz one another. In this way the benefits of an exchange of ideas and of the increased enthusiasm arising from association will be derived. It is suggested that county superintendents might be able to work out a plan whereby a few sets of these publications could be exchanged between groups of teachers in the same county, and thus be used as the basis of systematic agricultural reading-club work.

A list of publications of the United States Department of Agriculture suggested for an agricultural reading course.

I. AGRONOMY.

Topic.	Title.	Publication.
Soils	Soil Fertility	Farmers' Bulletin 257.
	The Renovation of Worn-Out Soils	Farmers' Bulletin 245.
	Soil Conservation	Farmers' Bulletin 406.
Fertilizers	Commercial Fertilizers	Farmers' Bulletin 44.
	Barnyard Manure	Farmers' Bulletin 192.
	Leguminous Crops for Green Manuring	Farmers' Bulletin 278.
Plant production	The Propagation of Plants	Farmers' Bulletin 157.
	Testing Farm Seeds in the Home and in the Rural School.	Farmers' Bulletin 428.
Cereal crops	Barley: Growing the Crop	Farmers' Bulletin 443.
	Corn Cultivation	Farmers' Bulletin 414.
	Seed Corn	Farmers' Bulletin 415.
	Harvesting and Storing Corn	Farmers' Bulletin 313.
	Oats: Growing the Crop	Farmers' Bulletin 424.
	Oats: Distribution and Uses	Farmers' Bulletin 420.
	Rice Culture	Farmers' Bulletin 417.
	Durum Wheat	Farmers' Bulletin 534.
Fiber crops	Cotton Seed and Its Products	Farmers' Bulletin 36.
	Sea Island Cotton	Farmers' Bulletin 302.
	Flax Culture	Farmers' Bulletin 274
Forage crops	The Adulteration of Forage Plant Seeds	Farmers' Bulletin 382.
	Our Native Pasture Plants	Yearbook Sep. 223.
	Alfalfa	Farmers' Bulletin 339.
	Red Clover	Farmers' Bulletin 455.
	Cowpeas	Farmers' Bulletin 318.
	Millets	Farmers' Bulletin 101.
	Rape	Farmers' Bulletin 164.
	Soy Beans	Farmers' Bulletin 372.
	Vetches	Farmers' Bulletin 515.
Truck crops	Good Seed Potatoes and How to Produce Them	Farmers' Bulletin 533.
	Potato Culture	Farmers' Bulletin 35.
	The Sugar Beet	Farmers' Bulletin 52.
	Sweet Potatoes	Farmers' Bulletin 324.
Miscellaneous field crops.	Broom Corn	Farmers' Bulletin 174.
	Growing and Curing Hops	Farmers' Bulletin 304.
	Tobacco Curing	Farmers' Bulletin 523.
	The Peanut	Farmers' Bulletin 431.
Crop pests	Weeds, and How to Kill Them	Farmers' Bulletin 28.
	Important Insecticides	Farmers' Bulletin 127.
	Cotton Wilt	Farmers' Bulletin 333.
	The Boll Weevil Problem	Farmers' Bulletin 512.
	The Smuts of Wheat, Oats, Barley, and Corn	Farmers' Bulletin 507.

A list of publications of the United States Department of Agriculture suggested for an agricultural reading course—Continued.

II. ANIMAL HUSBANDRY.

Topic.	Title.	Publication.
Bees	Bees	Farmers' Bulletin 447.
Birds	Some Common Birds	Farmers' Bulletin 54.
	Some Common Game, Aquatic, and Rapacious Birds in Their Relation to Man.	Farmers' Bulletin 497.
	Fifty Common Birds of Farm and Orchard	Farmers' Bulletin 513.
	Does it Pay the Farmer to Protect Birds?	Yearbook Sep. 443.
Cattle	The Dairy Herd	Farmers' Bulletin 55.
	Breeds of Dairy Cattle	Farmers' Bulletin 106.
	Tuberculosis	Farmers' Bulletin 473.
Hogs	Pig Management	Farmers' Bulletin 205.
	Hog Cholera	Farmers' Bulletin 379.
Sheep	Raising Sheep for Mutton	Farmers' Bulletin 96.
Poultry	Standard Varieties of Chickens	Farmers' Bulletin 51.
	Ducks and Geese	Farmers' Bulletin 64.
	Turkeys	Farmers' Bulletin 200.
	The Guinea Fowl	Farmers' Bulletin 234.
	Poultry Management	Farmers' Bulletin 287.
Feeds and feeding	The Feeding of Farm Animals	Farmers' Bulletin 22.
	Sheep Feeding	Farmers' Bulletin 79.
	Principles of Horse Feeding	Farmers' Bulletin 170.

III. HORTICULTURE.

Fruits	Small Fruit Culture for Market	Farmers' Bulletin 47.
	The Home Fruit Garden	Farmers' Bulletin 154.
	Pruning	Farmers' Bulletin 181.
	The Apple and How to Grow It	Farmers' Bulletin 113.
	Grape Propagation, Pruning, and Training	Farmers' Bulletin 471.
	The Pear, and How to Grow It	Farmers' Bulletin 482.
	Fungicides and Their Use in Preventing Diseases of Fruits.	Farmers' Bulletin 243.
	Information about Spraying for Orchard Insects	Yearbook Sep. 480.
Flowers	Annual Flowering Plants	Farmers' Bulletin 195.
Vegetables	The Home Vegetable Garden	Farmers' Bulletin 255.
	Frames as a Factor in Truck Growing	Farmers' Bulletin 460.
Landscaping	Beautifying Home Grounds	Farmers' Bulletin 185.
	Lawn Soils and Lawns	Farmers' Bulletin 494.

IV. FORESTRY.

General	Primer of Forestry, Part I: The Forest	Farmers' Bulletin 173.
	Primer of Forestry, Part II: Practical Forestry	Farmers' Bulletin 358.
	Trees of the United States Important in Forestry	Yearbook Sep. 112.
Tree planting	Forest Planting and Farm Management	Farmers' Bulletin 228.
	Tree Planting by Farmers	Yearbook Sep. 566.
Forest influences	Surface Conditions and Stream Flow	Forest Ser. Circ. 176.
Forest fires	The Protection of Forests from Fires	Forest Ser. Bul. 82.
	Forest Fires	Forest Ser. Bul. 117.
Wood preservation	The Preservative Treatment of Farm Timbers	Farmers' Bulletin 381.
Forest conservation	Progress in Saving Forest Waste	Yearbook Sep. 534.

V. AGRICULTURAL ENGINEERING.

Farm buildings	Practical Suggestions for Farm Buildings	Farmers' Bulletin 126.
	Modern Conveniences for the Farm Home	Farmers' Bulletin 270.
Farm mechanics	The Use of Concrete on the Farm	Farmers' Bulletin 461.
	Corn Harvesting Machinery	Farmers' Bulletin 303.
	The Cream Separator on Western Farms	Farmers' Bulletin 201.
	The Use of Alcohol and Gasoline in Farm Engines	Farmers' Bulletin 277.
	Repair of Farm Equipment	Farmers' Bulletin 347.
Roads	The Use of the Split-Log Drag on Earth Roads	Farmers' Bulletin 321.
	Sand-Clay and Burnt-Clay Roads	Farmers' Bulletin 311.
	Macadam Roads	Farmers' Bulletin 338.
	Benefits of Improved Roads	Farmers' Bulletin 505.
Drainage	Drainage of Farm Lands	Farmers' Bulletin 187.
Irrigation	Practical Information for Beginners in Irrigation	Farmers' Bulletin 263.
	How to Build Small Irrigation Ditches	Farmers' Bulletin 158.

A list of publications of the United States Department of Agriculture suggested for an agricultural reading course—Continued.

VI. AGRICULTURAL TECHNOLOGY.

Topic.	Title.	Publication.
Dairying	Butter Making on the Farm	Farmers' Bulletin 241.
	Cheese Making on the Farm	Farmers' Bulletin 166.
	The Care of Milk and Its Use in the Home	Farmers' Bulletin 413.
Sirup and sugar making	The Production of Maple Sirup and Sugar	Farmers' Bulletin 516.
	Sorghum Sirup Manufacture	Farmers' Bulletin 477.

VII. AGRICULTURAL ECONOMICS.

Farm management	What Is Farm Management	Bur. Pl. Ind. Bul. 259.
	Types of Farming in the United States	Yearbook Sep. 487.
	Replanning a Farm for Profit	Farmers' Bulletin 370.
Farm labor	The Supply and Wages of Farm Labor	Yearbook Sep. 528.
	Seasonal Distribution of Labor on the Farm	Yearbook Sep. 567.
Farm accounts	Farm Bookkeeping	Farmers' Bulletin 511.
Marketing	Marketing Farm Produce	Farmers' Bulletin 62.
	Cooperation in the Handling and Marketing of Fruit	Yearbook Sep. 546.

VIII. AGRICULTURAL EDUCATION.

General	Education for Country Life	Office Expt. Stas. Circ. 84.
	The American System of Agricultural Education	Office Expt. Stas. Circ. 106, Rev.
	The Teaching of Agriculture in the Rural Common Schools.	Office Expt. Stas. Circ. 60.
School gardens	The School Garden	Farmers' Bulletin 218.
	Forest Nurseries for Schools	Farmers' Bulletin 423.
Agricultural clubs	Boys' and Girls' Agricultural Clubs	Farmers' Bulletin 385.
	Organization and Instruction in Boys' Corn-Club Work	Bur. Pl. Ind. Doc. 803.
Special days in schools	Arbor Day	Forest Service Circ. 96.
	Bird Day in the Schools	Biolog. Survey Circ. 17.
School equipment	The Use of Illustrative Material in Teaching Agriculture in Rural Schools.	Yearbook Sep. 382.

ADDITIONAL COPIES of this publication may be procured from the SUPERINTENDENT OF DOCUMENTS, Government Printing Office, Washington, D. C., at 5 cents per copy

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 8

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
September 27, 1913.

THE WESTERN CORN ROOTWORM.

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The western corn rootworm (*Diabrotica longicornis* Say) derives its common name from the fact that the larva (fig. 1) was first observed attacking the roots of corn in the Middle West. Its larval habits, its life cycle, and the appearance of the adult insect (fig. 2) are all entirely different from those of the southern corn rootworm (*Diabrotica duodecimpunctata* Oliv.), though the worms themselves are exceedingly alike in appearance. In figure 1 the larva is extended at full length, as when feeding, having been drawn from living individuals.

The beetles (fig. 2) in life are about the size of the striped cucumber beetle (*Diabrotica vittata* Fab.), but smaller and less robust than the southern corn rootworm, and are entirely of a green or yellowish-green color, except the eyes, which are black. The farmer will be most likely to observe these feeding among the silk of the ears and the pollen of corn during late August and September, though the writer has seen them enter houses in the country at night, being attracted by the evening lamps. An abundance of these beetles in a cornfield should be a distinct warning that the field should not be planted to corn the following year, but that it should be devoted to wheat, oats, barley, rye, or to any crop other than corn.

Fig. 1.—The western corn rootworm (*Diabrotica longicornis*): Larva, or "worm." Much enlarged. (Original.)

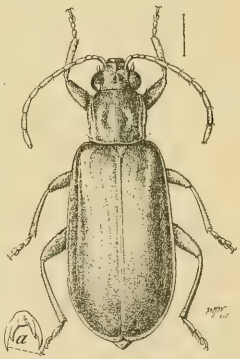

Fig. 2.—The western corn rootworm: Adult, or beetle; *a*, claw of hind leg. Much enlarged. (Original.)

SEASONAL HISTORY.

The eggs (fig. 3) are minute, yellowish-white objects, having to the unaided eye much the appearance of minute grains of white sand.

They are deposited mostly in late August and in September, in shallow crevices in the ground, more often among the brace roots of the corn. These eggs hatch the following May and June, and the larvæ, always nearly white in color, attack the roots of the corn and never burrow into the lower stem as does the southern budworm. (See fig. 5.) After completing their growth the larvæ abandon the corn roots and construct earthen cells in the soil, within which they change to pupæ (fig. 4), which are white like the larvæ, and then, during late July and August, to adults or beetles. There is therefore only one generation annually. The beetles may perhaps live over winter in extreme southern Texas, but they do not do so farther north, where they are of the greatest economic importance.

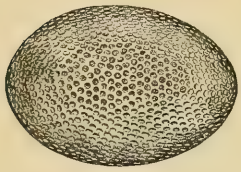

FIG. 3.—The western corn rootworm: Egg. Highly magnified. (Original.)

DISTRIBUTION.

The species occurs from Nova Scotia southward to Alabama and Mexico, westward to southern Minnesota and South Dakota, and thence south to southern New Mexico.

Curious enough, but a matter of decided economic importance, is the fact that its area of destructive abundance does not include all of the territory which it inhabits. The greatest destruction has been wrought, so far as known, in Illinois, Indiana, Ohio, Iowa, Missouri, South Dakota, Nebraska, Tennessee, and probably Kentucky.

HISTORY OF THE INSECT AND ITS RAVAGES.

The beetle was described in 1823 by Mr. Thomas Say, from specimens taken by him while connected with the Maj. Long expedition to the Rocky Mountains, and its habitat was given by him as the Arkansas Territory.[1]

FIG. 4.—The western corn rootworm: Pupa. Much enlarged. (Original.)

No facts concerning the habits of this insect were recorded until the year 1866, when specimens of the beetles were referred to Mr. B. D. Walsh by Prof. W. S. Robertson, of Kansas, who found them in large numbers on imphee or sorghum, their natural home being a large thistle. Mr. Walsh, in acknowledging the receipt of the specimens, stated that he had taken three specimens many years before on flowers in central Illinois.[2] Eight years later, in August, 1874, Mr. H. Webber, of Kirkwood, Mo., sent some larvæ and pupæ to Prof. Riley, with the complaint that the former were burrowing into the roots of his corn and doing considerable damage. In July,

[1] Journ. Acad. Nat. Sci. Phila., vol. 3, p. 460, 1823.
[2] Practical Entomologist, vol. 2, p. 10, 1866.

1878, Prof. Riley[1] again received larvæ, this time from Mr. G. Pauls, of Eureka, Mo.,[2] and from these he reared adult beetles on the 14th of the following month.

During the spring of 1874 the writer began to collect Coleoptera in the vicinity of Waterman, Dekalb County, Ill., but during this and the following two years obtained only a single beetle of this species. This single specimen, taken by the writer in the summer of 1874, was captured in a field of corn, and the failure to secure more individuals during the next two years will indicate the rarity of the insect at that time. Within seven or eight years, however, it had become so abundant throughout the neighborhood, and indeed on the same farm, then as now owned by the writer, as to render it impossible to secure more than a single full yield of corn without changing for a year to some other crop. Up to that time corn had generally been successfully grown on the same ground for a number of consecutive years. The writer's observations in Dekalb County reflect with surprising accuracy the conditions that obtained throughout the corn-growing sections of Illinois, as shown by the information brought together by Dr. S. A. Forbes, then as now State entomologist[3] of Illinois. May, 1884, the writer ceased to be connected with Dr. Forbes's office and became associated with the Division of Entomology of this department and was soon thereafter transferred from Illinois to La Fayette, Ind.

FIG. 5.—Work of the western corn rootworm in roots of corn; at right, rootworm in situ. (Original.)

The principal damage, as previously indicated, is caused by the larvæ, and since 1882, in localities where no preventive measures have been used, the damage to the corn crop has been very serious. In 1885 Mr. Moses Fowler, of La Fayette, Ind., owner of an extensive tract of land, estimated his loss during that season through the ravages of the pest at $16,000, or about 15 per cent of the entire crop. On the basis of this estimate the loss sustained in 24 of the corn-

[1] American Entomologist, vol. 3, p. 247, 1880. (Note.—See "Roots of corn injured by some unknown insect." American Entomologist, vol. 2, p. 275, 1870.)

[2] Report of the Commissioner of Agriculture for 1878, p. 208, 1879.

[3] 14th Rept. State Ent. Ill., pp. 10–31, 1883.

producing counties of that State for that one year would amount to nearly $2,000,000.[1] Although the pest is much more destructive on high or tile-drained lands, Prof. Forbes in 1886 reported serious injury to a field in southern Illinois which had been under water for three weeks during the spring.[2] There is no indication that the insect is susceptible to meteorological influences, although the effect of its ravages is aggravated by an extremely dry season. In fact, the extreme effect of the larva upon the plants is very similar to that of severe drought.

Under date of March 7, 1887, Mr. B. F. Ferris, Sunman, Ind., a close observer, communicated with the writer as follows:

> There has been for a number of years something, I know not what, working at the roots of our corn, so that in some seasons the corn does not have roots sufficient to support it, anything like a fresh breeze blowing it down, there being scarcely any brace roots.

Sunman is in southeastern Indiana, close to the White and Ohio River Valleys, which connect with the lower Big Miami Valley in western Ohio, and when the writer was transferred from Indiana to Ohio, June 1, 1891, he at once became interested in learning whether this corn rootworm had extended its depredations into the cornfields of Ohio. The first report of injuries came from Sater, Hamilton County, in the extreme southwestern part of the State, during September, 1892, the charge being that the beetles ate the silk from the ears of sweet corn before the kernels had become fertilized.

A careful survey of extreme western Ohio during the summer of 1893 revealed the beetles in cornfields throughout the country drained by tributaries of the upper Wabash River, and throughout the valley of Big Miami River, but not beyond, to the northward or eastward. A similar survey, made in the summer of 1894, revealed the pest in the region of the upper Maumee River in the northwestern part of the State and in the valley of the Little Miami River on the east. In 1895 the pest had reached the Scioto River Valley, almost if not quite halfway from east to west across the State, and from Columbus southward to the Ohio River; while in the opposite direction its range extended from Columbus more or less irregularly northwestward to the Michigan line in Fulton County. Still later it appeared farther eastward, in the upper valley of the Muskingum River. There was no guesswork in these surveys, as they were carefully made in person by the writer, who rode over the country each year when the adult insects were abroad, examining fields and noting the presence or absence of the beetles. The following year these observations were verified through larvæ found at work by the writer or observed and sent to him by farmers.[3]

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[1] Indiana Agricultural Report, p. 188, 1885.
[2] Entomologica Americana, vol. 2, p. 174, 1886.
[3] Ohio Agr. Exp. Sta., Bul. 68, pp. 39–41, maps 1–2.

It has been thus the writer's good fortune to follow personally the destructive spread (though not the actual diffusion) of the species throughout three States and from the years 1874 to 1902, both inclusive.[1]

During the years 1911 and 1912 an outbreak of this insect was studied in the Duck River Valley, middle Tennessee, by Mr. George G. Ainslie. In 1913 the same observer found the larvæ attacking corn in the bottom lands of the Tennessee River about Chattanooga, Tenn.

The pest appears to be making its way into and throughout the bottom lands of rivers flowing through the Southern Atlantic and Gulf States, precisely as it has been observed to do in Indiana and Ohio.

DIFFICULTY IN DETECTING INJURY TO CORN.

As will have been noted, the work of the larvæ is very obscure and few farmers are likely to detect them at work in the roots during June and July, while it would be simply impossible for the farmers, even if they did discover them, to connect them definitely with the little green beetles that swarm in the silk of the ears during summer and early fall.

FOOD OF THE BEETLES.

In the cornfield the food of these beetles is made up of corn silk and pollen. Rarely do they eat of the unripe kernels at the tips of the ears, and then only when birds have previously pecked into these kernels. Outside the cornfields the writer has found them in the blossoms of thistle, sunflower, goldenrod, cucurbits, cotton, clover, and rose, and on the leaves of cucumber and beans, while the species has been reported to him as eating into ripe apples where the skin had been previously ruptured by other causes. Dr. Forbes has found spores of fungi and pollen of smartweed in their stomachs. More recently Mr. George G. Ainslie has found the beetles feeding on the leaves of corn and on the pollen of the evening primrose and asters.

[1] *Changed conditions that may have caused a change of habit in the insect.*—As the writer well remembers, the principal crop in many portions of Illinois, especially throughout the prairie country, up to 1862 was spring wheat. Influences of the Civil War at that time brought the price of pork up to a point where its production became a most profitable occupation for the farmer. At the same time wheat growing declined rapidly, the acreage being devoted to corn in order to afford food for the increasing number of hogs. In those days crop rotation received scant attention from the ordinary farmer, and corn was more often than otherwise planted year after year on the same ground. How soon it was, after this change in the principal crop from wheat to corn, that these beetles, attracted to the cornfields perhaps by the enormous amount of pollen found there as well as by the equally inexhaustible food supply offered by the silk, began to deposit their eggs and develop in these fields, it is not possible to say. We do know, however, from the records already given, that injuries from the larvæ began to be noticed in 1874, about 10 or 12 years after this change in production of wheat and corn took place, thus giving us at least a clue to the primary causes which seem to have changed the food of the insect to a cultivated crop.

EFFECTS OF ATTACK OF THE LARVÆ.

The initial effect of the work of the larvæ in the roots of corn is a shortening of the ears, leaving long tips devoid of kernels. As the infestation and injury increase, plants fail to develop ears, and finally a dwarfing of the stalks occurs. The appearance of the crop is precisely the same as it would be if the land were impoverished. Indeed many farmers, ignorant of the real trouble, claim that their soil has "run out" and is incapable longer of producing corn. One farmer insisted that his corn was damaged by careless cultivation. For this reason much injury may be done by the pest before it is recognized at all.

NATURAL ENEMIES.

The Biological Survey has found specimens of *Diabrotica longicornis* in stomachs of the nighthawk (*Chordeiles virginianus*) and the wood pewee (*Myiochanes virens*).

The natural enemies of this species are exceedingly few, the principal one being the parasitic fly *Celatoria diabroticæ* Shim., figured in Bulletin 5 of this department as an enemy of the adult of the budworm. Mr. George G. Ainslie, however, has found that the beetles are attacked by the so-called chinch-bug fungus, *Sporotrichum globuliferum*. The larvæ of the click-beetle *Drasterius elegans* Fab. are also frequently found among those of this species and may destroy some of them.

CROP ROTATION AS A PREVENTIVE MEASURE.

In all of the history of this, one of the most destructive pests in the cornfield, there is not an instance on record in which corn has been injured when planted on land following a crop of small grain, such as wheat, rye, barley, or oats. Except on grounds subject to overflow, which prevents a rotation of crops so that corn is or must be grown for two or more successive years, this pest is one of the easiest to control. Two instances only need be cited in order to prove this fact.

In Dekalb County evidence of the protection afforded by the rotation of crops is afforded on a much larger scale. On a farm of 4,600 acres owned by Hon. Lewis Steward, near Plano, rotation of crops has been the regular rule; 1,600 acres of this land was planted to corn this year, and 700 acres were carefully examined by Mr. Webster. In August only 10 acres of this entire tract was found affected by the corn rootworm, and this was where, in the rearrangement of the fields, a small tract of ground happened to have been planted to corn the previous year. All about Mr. Steward's place, on farms where rotation was not systematically practiced, the damage done was serious and general.[1]

[1] Quotation from 14th Rept. State Ent. Ill., p. 29, 1885.

The second instance is that of Mr. Moses Fowler, previously mentioned on page 3. At the time referred to (1885) the Fowler estate, comprising a single tract of about 18,000 acres, near Fowler, Ind., was farmed by tenants and there were about 10,000 acres of corn growing on the premises. Some of the fields were but slightly injured and these were such as had either produced oats or grass within two or three years. Other fields were damaged from 10 to 75 per cent or more. Mr. Fowler, the following spring, directed his tenants to sow 5,000 acres of the worst infested fields to oats and the remainder of the 10,000 acres were sown to oats the second year. Thereafter no attempt was made to grow corn two successive years on the same ground, and as a result the pest was eliminated and no further damage was sustained.

What one man can do, who has control of thousands of acres, a community can also accomplish if the people combine and follow a similar course of procedure.

Dr. Forbes, in his thorough and painstaking investigations of the insect in Illinois, has found many similar instances of the efficiency of crop rotation in eliminating the insect from cornfields. These data have been supplemented by later studies of the writer and by other observations made by him extending over the same period in other States; so that there is no longer the slightest doubt of the efficiency of this measure, which is now considered essential to good farming.

POSSIBLE EXCEPTIONS TO EFFICIENCY OF CROP ROTATION.

In this period of nearly 40 years only a few possible exceptions to the effectiveness of crop rotation have come to the writer's knowledge. One of these came from a farmer in northern Illinois whom the writer knew personally and who in 1886 complained of the attack of these larvæ on his corn, which was planted on ground that had been devoted to clover and timothy the year previous. This farmer was familiar with the pest and its work and sent specimens of the larvæ. The only explanation that could be offered for this unusual injury was that the beetles forsook the cornfields after the pollen had ceased to fall from the tassels and the silk of the ears had become too dead and dry to afford them food, and that some of the females which had not already finished oviposition made their way to the clover field, fed in the blossoms, and oviposited in the soil, thus giving rise to the larvæ that the next year attacked the corn which followed the clover crop in this field.

The second complaint came from a farmer in Indiana who for two years had fed considerable corn fodder to stock in a pasture of blue grass and timothy. After plowing up this ground and planting it

to corn he reported that the crop was attacked by these worms. In this case no specimens accompanied the complaint.

It goes without saying that the beetles are found and must develop where very little corn is grown, but time has shown that there is little danger to be apprehended from these.[1]

Quite recently Mr. C. N. Ainslie, of this bureau, has found slight injury to corn in fields in Nebraska where this crop has followed small grain.

DEPREDATIONS ON LAND SUBJECT TO OVERFLOW.

The frequent submergence during fall, winter, or early spring, even for weeks at a time, of fields in which the eggs of these beetles have been deposited does not seem to affect such eggs in the least. Throughout the country north of the Ohio and Arkansas Rivers it is these low bottom lands that are kept most continuously in corn, and therefore it is here that in later years the danger from the pest is greatest. This is not, so far as now known, true of the lower Mississippi Valley, for the reason that planters there rotate with cotton, otherwise the ravages of the insect would probably be felt there as well as in the more northern States, as the writer has observed the beetles feeding on the pollen of the cotton bloom. Thus we see that throughout the country it is only where crop rotation is neglected that damage is at all to be feared.

[1] *Possible origin of a corn-feeding race.*—It will be noticed that Mr. B. D. Walsh, the first State entomologist of Illinois, found three of these beetles in central Illinois many years prior to 1866 (Practical Entomologist, vol. 2, p. 10, 1866). Mr. Ottoman Reinecke, of Buffalo, N. Y., wrote the author in 1893 that he had, prior to 1880 and for some years, collected the beetles in abundance on willow along the margin of a creek near the city during July and August; while Mr. W. H. Harrington wrote the author years ago of his finding them in Nova Scotia. Thus it is clearly shown that the eastward advance each year, as previously recorded, does not represent the real advance of the species. It represents the advance of a race that feeds on the pollen and silk of corn, some of whose larvæ develop in the roots, the adults from these spreading from field to field and under favorable conditions giving rise to myriads of worms that feed on the roots and destroy the crop. The origin of this race appears to have been the prairie country in Illinois, which in many places begins at the Mississippi River and extends into northwestern Indiana. It is true that the first reports of injury to the roots of corn by the larvæ came from Eureka and Kirkwood, Mo., both of which are near St. Louis; but just across the Mississippi River in Illinois are wide stretches of prairie country which near the river are subject to overflow.

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U.S. DEPARTMENT OF AGRICULTURE

No. 9

Contribution from the Forest Service, Henry S. Graves, Forester.
December 5, 1913.

AN ECONOMIC STUDY OF ACACIAS.

By Charles Howard Shinn,
Forest Examiner.

PURPOSE OF THE STUDY.

The acacias are so valuable as a source of tanning material and of timber, and are so well adapted to the reclamation of sandy and semi-desert lands that the introduction and culture of these exotics into certain portions of the United States may prove extremely profitable.

To a certain extent parallels exist between the culture, in America, of eucalypts and acacias. Both were introduced in California about the same time, and both have thrived there. Commercially, too, their ranges are practically identical, though acacias do not make as large demand upon the soil. In both cases, however, the lack of frost hardiness limits their range.

The aim of this bulletin is to call attention to the economic importance of the leading acacias with the idea of bringing about more general planting.

THE GENUS ACACIA.

ITS EXTENT.

The acacias form the most characteristic group in the suborder Mimoseæ, of the great bean family Leguminosæ, represented in the United States by such trees as black locust (*Robinia pseudacacia*), honey locust (*Gleditsia triacanthos*), coffee tree (*Gymnocladus dioicus*), and redbud (*Cercis canadensis*). They are, in the main, natives of Australia, which has about 300 species. There are 150 other species scattered over the world, principally in Asia, Africa, and America, with one important species, the koa, in the Hawaiian Islands. Of the 450 not more than 75 have a known economic value, and not more than 50 are in general cultivation, though 150 species are growing in nurseries, gardens, and arboretums in the United States. A compilation of California nursery catalogues made in 1911 showed 103 species listed. The authorities of Golden Gate Park, San Francisco, enumerate 60 species growing within the park.

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Besides the 450 species there are many varieties developed through cultivation. Further, much confusion exists as to the proper identification, not only of the acacias but of closely related genera, which are sometimes confused with the true acacias. An example of this is found in the so-called *Acacia lophantha*, which is an albizzia, as is the pink-flowered "Constantinople acacia." The flowers of the true acacias are usually yellow, and are produced in globose heads variously arranged; those of the albizzias are generally borne as spikes, similar to those of the Australian "bottle brush" (*Melaleucas*), and are seldom yellow, though some are a greenish white.

NOMENCLATURE.

The difficulties of identification have led to equal difficulties of nomenclature, or, rather, the confusion in either case has led to confusion in the other. Except for the species of greatest economic value, which have been longest in cultivation, the nomenclature is so mixed in California that acacias are still being sent to Dr. Maiden, director of the Sydney Botanic Garden, for identification.

Mr. Ernest Braunton, of Los Angeles, has done much in recent years to secure the correct identification of the acacias planted for ornament in southern California. Dr. Franceschi and Mr. P. Reidel, of Santa Barbara, and Miss Katherine Jones, of the University of California, at Berkeley, have worked with the acacias to the end that the synonyms may be all weeded out, and that the various species grown in California, where acacias have been most extensively planted in this country, may be accurately known.

The chief difficulty has been with the so-called *decurrens* group, and the problem has been to distinguish between species and mere varieties.

The classification made by Dr. J. H. Maiden[1] seems to be both culturally and scientifically correct, and its general adoption offers the best escape from present confusion in American nomenclature. According to this (1) *Acacia decurrens*, or *decurrens* var. *normalis* (Willd. and Benth.), is the "black wattle"; (2) *Acacia decurrens* var. *mollis* (Benth.) is the *Acacia mollissima* (Willd.), and is the leading "green wattle"; (3) *Acacia decurrens* var. *pauciglandulosa* (F. von M.) also is known usually as "green wattle"; (4) *Acacia decurrens* var. *dealbata* (F. von M.) is the leading "silver wattle."

These four wattles and two or three others of lesser importance pass into each other by successive gradations. They show cultural differences, however, and marked variations in yield of tan bark. The nurseryman naturally chooses the more floriferous and shapely form of *Acacia decurrens*, but the commercial planter must consider bark yields and proportion of tannin.

[1] "Wattles and Wattle Barks," third edition, pp. 103, Sydney, 1906.

CHARACTERISTICS OF VARIOUS SPECIES.

SOIL AND MOISTURE REQUIREMENTS.

Acacias form one of the most conspicuous associations of all those which group themselves close to deserts. While they do not constitute a true desert species, they nevertheless carry tree life well into the desert regions, becoming shrubby and scattered. In fact, some species, such as *Acacia greggi*, one of the most valuable lac-insect bearing species, will thrive with only 3 inches of rainfall; some grow on inland sand dunes far from ocean influences. With a few notable exceptions, the acacias are preeminently adapted to poor soil and rainless summers and to semiarid conditions, though most of them respond to good soil and abundant moisture. Their great drought-resisting qualities come from their deep, strong root systems and from their leaves, which are chiefly phyllodes, or flattened stems, with sensitive specialized powers of movement by which evaporation may be greatly lessened.

A light, warm, well-drained soil, if cultivated, will produce rapid growth, and the rich and heavy soils which some of the eucalypts demand for their best development are not necessary for the acacias. The most prominent exception to this is *Acacia melanoxylon*, or "black wood," which produces choice timber but has little value for tanning unless the tannic acid is concentrated by the extract method. This is a river-bottom species, associated with *Eucalyptus globulus* and other trees of that type.

Acacias readily adapt themselves to a heavier precipitation and more tropic conditions than characterize their native soil, as proved by many years of growth in the Hawaiian Islands and on the Natal coast of Africa. Indeed, many species, as with the eucalypts, when introduced elsewhere, may grow even more rapidly than in their native region. But mainly the significant fact about the tree, so far as moisture conditions are concerned, is that it does not require a heavy annual rainfall nor any summer rain. It is this characteristic which renders it valuable on the southern Pacific coast and in the Southwest. It must be kept in mind that the trees are only half hardy as regards frost, and will not endure a temperature below 16° F. or 20° where the cold is likely to be sustained.

So far as known, no other semitropic trees of high economic value possess to so great an extent the ability to thrive upon and to improve a great variety of arid and sterile soils. Through their agency large areas of land unfit for ordinary cultivation, and at present producing only a scanty pasturage at best, may be reclaimed and utilized. Recent discoveries in the nitrogen-fixing qualities of the legumes point to the possibility of a hitherto unrecognized value in acacia growing.

FORMS.

With so many and so varied species there can be no form and no rate of growth common to the whole genus. Some acacias are mere herbaceous plants; others are towering trees; most are shrubs, and some, in fact, are vines or climbers. In certain instances the same plant which has a creeping habit when exposed to cold salt winds on the seashore will be able, a little farther inland, to assume an erect form and, where still better protected, to become a fully developed tall tree. One authority describes these size variations thus:

> Some tiny species hardly exceed 3 or 4 inches in height, and may be crushed like the grass of the field. Most of them are shrubs, or trees of moderate size, while at least two species attain the stature of large forest trees, both of them being found to measure up to nearly 4 feet in diameter, while one has been found to attain a height of over 100 feet, and the other the extraordinary height of 150 feet.[1]

The largest acacia is probably *Acacia bakeri*, of which specimens have been described as over 160 feet high, with a clear length of from 50 to 60 feet and diameters of from 2 to 4 feet. Other large trees are *Acacia melanoxylon*, *A. longifolia*, *A. dealbata*, and *A. decurrens*, all of which may attain a height of 100 feet or more. *A. salicina*, *A. excelsa*, *A. elata*, *A. prominens*, *A. pendula*, and *A. binervata* are also large trees, ranging from 30 to 80 feet in height.

Those which are most used for commercial products, and particularly for tannin, do not need to attain large size or great age before the products are merchantable. Thus they can be managed on a shorter rotation than most forest trees.

ENEMIES.

Insects.

The acacias first planted in California grew so fast, bloomed so soon and so freely, and were so free from disease that most horticulturists felt sure that acacias would become the most important shade trees for California. This enthusiasm was particularly marked from 1870 to 1876. It was like the subsequent fad in the Middle West for the hardy catalpa or the more recent furore over eucalypts in California. There followed, however, a sharp reaction because of the ravages of various scale insects, and many trees were cut down. But after the introduction of the vedalia, which destroyed the cottony cushion scale, and the adoption of the various sprays it was found that the acacias are not peculiarly subject to injury by scale insects, and are no more often a haven for the pests than are oaks, olives, and various orchard trees. The most dangerous insect enemy,

[1] J. H. Maiden, "Wattles and Wattle Barks," Government Printer, Sydney, New South Wales.

[2] For information on insects and methods for their control the reader should apply to the State Experiment Station, Berkeley, Cal., or to the Bureau of Entomology, United States Department of Agriculture, Washington, D. C.

according to various observations, is the cottony cushion scale (*Icerya purchasi*).

The scale insects have sucking mouthparts and subsist on the juices from the inside of the tree; for this reason they are hard to combat, because it is difficult to poison their food supply. Since they live upon the sap, they must necessarily lessen the vitality of a tree, especially where there is a very dry summer climate. If they are very numerous, trees can not thrive and may even be killed. Scale insects, besides robbing the tree of nourishment, harm the tissues, close the pores by their excretions, and supply conditions under which fungi may get a good start. All these are much less serious with the acacias than the actual loss of sap; and where the water supply is ample the actual harm done by the scale is very slight. But since one of the chief values of the acacias is their adaptability to very arid regions, the scale insects should be destroyed wherever they exist, and care should be taken to establish plantations from seed or from thoroughly disinfected plants.

Two insect enemies of the wattle in Natal, reported by Mr. David G. Fairchild, are a bag worm, which destroys great quantities of foliage and checks the growth of the trees, and a more destructive locust, which can retard growth to the equivalent of more than a year. The bag worms are collected and burned, and the plague of locusts is prevented by spreading poisoned molasses about their breeding places. A special locust expert is employed by the Natal Government; with his corps of laborers he poisons all the principal breeding places of the pest.

Other insects attack the black wattle (*Acacia decurrens*) in Australia.[1] Of these, one is an undescribed species of weevil (*Bruchus* sp.) which was found in seeds purchased in San Francisco, and presumably was introduced into California from Australia or South Africa in the seed. Another is a long-horned beetle (*Oyelle crinicornis*) of almost world-wide distribution in the Tropics; several other insects do more or less harm.

Fire.

There seem to be various opinions about the fire-resistant qualities of acacias, though they are generally considered very sensitive to fire. Some authors have stated that they do not burn readily, and the wattles in particular have been recommended for planting as fire breaks, not so much because they are not easily ignited but because their growth is so dense, both above and below ground, that no ground cover can thrive, and there is, therefore, beneath the trees an area free of vegetation. On the other hand, Dr. Maiden says [2]

[1] "The Black Wattle," by Jared G. Smith, Bulletin No. 11, Hawaii Agricultural Experiment Station.
[2] "Wattles and Wattle Barks," Sydney, 1906.

that wattle plantations must be protected from fire by fire breaks "and also by the removal of the inflammable brush from among them. At the same time, the finely divided foliage of *Acacia decurrens* makes it the most susceptible of the commercial wattles to destruction by fire." In Natal, according to Mr. David G. Fairchild—[1]

> The greatest enemy of the wattle is the grass fire. From the surrounding prairie such fires spread into the plantations and destroy them. To prevent this, nearly 50 miles of fire breaks, made by planting broad strips of prairie, have been constructed about the forests, and the expense of this adds materially to the original cost of establishing a wattle estate.

Another author, writing from the Transvaal,[2] calls attention to the prevailing notion that "it is commonly supposed that wattles a few years old are safe from fire, and in fact make good fire breaks. This, however, is not the case, and many disastrous fires have entirely destroyed wattle plantations." A fire which merely defoliated the trees scorched the bark and rendered it valueless. "From this it will be seen how very necessary it is to protect the plantations from fire as far as possible. This can best be done by plowing or burning wide belts around the trees," and by dividing the plantation into blocks by means of roads, which must be kept clean.

Other Injuries.

Frost is, of course, to be avoided, though many species will stand temperatures of 20° F. if not too prolonged. Hail may do considerable damage by bruising the bark and breaking off shoots. Crooked stems and branches have resulted from hail injury.

A black-wattle plantation in Hawaii suffered a loss of 20 per cent due to three causes—from being overmature, from stock browsing, and from insect enemies. Goats are particularly injurious, and their severe cropping will altogether destroy growth.

HISTORY OF ACACIA CULTURE IN CALIFORNIA.

Those who first planted acacias in California obtained only the species which had been planted on the Atlantic coast and in the Middle West. Many of these species were not in the least adapted to the California climate. It was then suggested that since western Mexico, Chile, and southern Europe had climates similar to that of California, acacias from these regions would be suitable, but introduction was slow and difficult. The Spanish settlements had furnished a few

[1] Bulletin 51, Bureau of Plant Industry, Miscellaneous Papers, "The Cultivation of the Australian Wattle," pp. 21–25.

[2] Lionel E. Taylor, Assistant Conservator of Forests, in Forestry Section of Transvaal Agricultural Journal, Jan., 1910, vol. 8, No. 30, Agricultural Department, Pretoria.

species which were extensively propagated, and one of them, *Acacia farnesiana*, familiar about the missions of San Diego and Santa Barbara, was grown by nurserymen in San Francisco, Los Angeles, and Sacramento as early as 1854. Potted acacias and acacia flowers, grown at Sacramento, were exhibited at one of the first agricultural fairs held in California, in 1855. An Australian acacia bloomed at Marysville before 1860.

The importation of acacia seed from Australia began in a curious way. A few of the Australians who came to California at the time of the gold fever brought over seeds and rooted plants and sold them to the nurserymen at high prices. By 1853 Col. Warren, who had established the California Farmer, was obtaining Australian seeds from these immigrants, and was soon importing direct from Sydney. In 1854 he was advertising acacia seed, and nurserymen in the vicinity of San Francisco were planting *Acacia decurrens* and *Acacia melanoxylon*. These two species were the pioneers of the Australian acacias in California. Acacias from these early importations were blooming and attracting attention in San Francisco, San Jose, and Sacramento by 1858.

By 1862 the late Julius Forrer, a German, for a long time the capable foreman of one of the University of California experiment stations, was growing in his nursery in San Francisco these species: *Acacia cyanophylla, A. cuneata, A. dealbata, A. homalophylla, A. linearis, A. longifolia A. lunata, A. melanoxylon, A. "mollissima"* (*A. decurrens* var. *mollissima*), *A. pendula*, and *A. receana*.

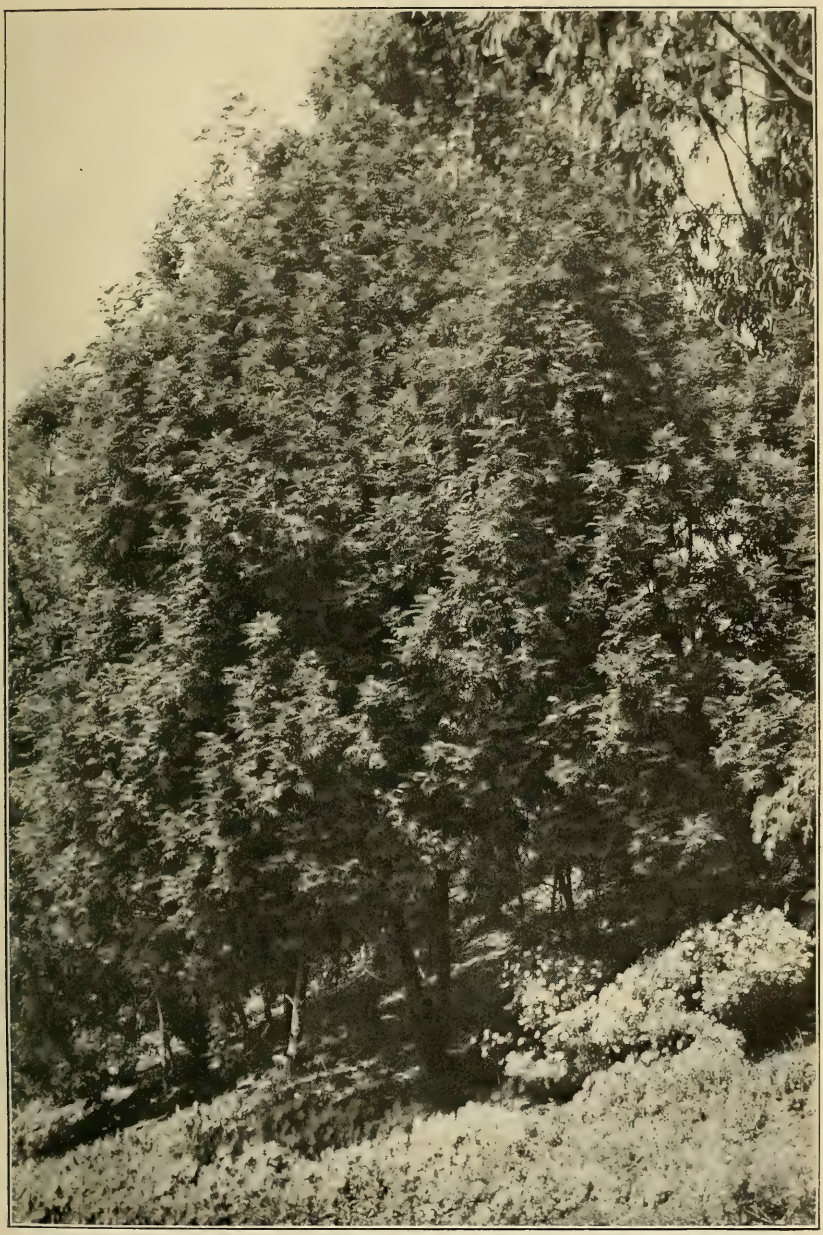
Between 1870 and 1875 enthusiam in acacia planting was at a high pitch. This was followed by a sudden reaction due to the introduction and depredations of scale insects. Since 1880, however, California nurserymen have increased their stock of acacias, and since 1900 sales have been much greater, especially in southern California, where some growers make a specialty of it. Mr. Wolleb, another German, of Fruitvale, Alameda County, bought trees from Forrer's nursery from 1862 to 1870 and tested many other species. In 1882 he published in the Rural Press a review of his experiments. He had tested *Acacia armata, argyrofolia, binervata, celestrifolia, cultriformis, cyanophylla, dentifera, discolor, farnesiana, extensa, pulchella, latifolia, saligna, linearis, longifolia, lunata, nigricans, nerifolia, receana, suavolens, verticillata, vestata*, and some others now dropped from cultivation.

Other Californians besides Mr. Wolleb made collections of acacias before 1880 and kept notes on their growth. The late Gen. John Bidwell planted some in Chico, Butte County, in the Sacramento Valley, and they are now magnificent specimens. A few were set out in Shasta City, about 200 miles north of San Francisco, and still flourish.

Mr. Alvinza Hayward, Mr. P. Nolan, and Mr. H. P. Livermore planted them extensively in Alameda County; J. de Barth Shorb made a 10-acre plantation in Los Angeles County about 1875. This plot has since been cut up into city lots, but some of the original trees remain.

The College of Agriculture of the University of California and the State Forestry Commission grew and distributed many acacias, and have published the results of successful investigations. The collection of acacias at Berkeley, the seat of the State university, was begun in 1872 with 30 species, and was subsequently augmented by many others. Parts of the arboretum were destroyed, however, to make way for new buildings. Acacias were planted at Chico and Santa Monica forestry stations, and at the latter place tannin determinations of the bark have been made. Acacia planting in Golden Gate Park, San Francisco, was begun by Mr. W. H. Hall, the superintendent, in November, 1870, when 1,200 acacias of 10 species were set out. Planting went on year after year under the supervision of the manager, Mr. John McLaren. In 1880 and 1889, 50,000 acacias were planted in the sands toward the western end of the park. In the years 1889 to 1892 not less than 50,000 trees, and usually 60,000 trees, were set out in a season, and in subsequent years from 5,000 to 20,000 were used each year, so that up to the present time about half a million have been planted. The Golden Gate Park nurseries still grow about 25,000 specimens every year, and they have more acacias and more kinds of acacias than anywhere else on the Pacific coast. This Golden Gate Park planting is such a remarkable example of sand-dune reclamation that it will be treated alone in a chapter devoted to that subject.

This review of acacia planting in California since 1852 shows that the field has been very fairly covered. Any person who desires to know whether a given species of acacia will thrive in any part of California is likely to find mature specimens within a reasonable distance. He may not find commercial or profit-yielding plantations, but he will find ample evidence of the adaptability of the tree to the soil and climate. Just as the olive and orange trees of the missions proved the suitability of the region to olive and orange groves, the many acacia trees, over a much wider range of country, show the commercial possibility of acacia plantations. The hardier acacias will flourish where the orange and olive will succeed. Nevertheless, many species have not yet been fully tested, and there is need of further systematic determination of the frost and drought limits, even of long-cultivated species; also for exact tests of bark yields and proportion of tannin. The naturalization of any exotic on a large scale requires much patience and money and involves complex problems.



A PLANTATION OF ACACIA DECURRENS MOLLIS IN GOLDEN GATE PARK, SAN FRANCISCO.

ACACIA ARABICA, ONE OF THE SOURCES OF GUM ARABIC, AT THE SANTA MONICA FOREST STATION, CALIFORNIA.

FIG. 1.—THICKETS OF ALBIZZIA LOPHANTHA NEAR THE OCEAN, GOLDEN GATE PARK, SAN FRANCISCO.

FIG. 2.—THICKETS OF ACACIA LONGIFOLIA ALMOST AT THE EDGE OF THE TIDE, GOLDEN GATE PARK.

The plant with the finer foliage is the acacia.

ECONOMIC USES.

The acacias were first spread abroad over the semitropic regions of the earth by reason of their easy culture, their adaptibility to many situations, and their attractiveness as shrubs or shade trees. Their wide range of economic uses, however, was very slowly recognized outside of Australia, where many species have long ranked with the eucalypts as profit-yielding trees. Some acacias have a remarkable value for the reclamation of sand dunes, whether they are seashore drifts or inland barrens. Many species furnish tanbark; others yield forage; others produce timber of notable quality; almost all are suited to ornamental plantings, and many are excellent for street trees and for shelter belts, and several furnish many special products of great economic value. In fact, various species of Australian acacias, according to Dr. Maiden, yield food, forage, medicine, fibers, gums, resins, kinos, perfumes, dyes, tannins (33 Australian species furnish tannin in commercial quantities), timbers, and ornamental finishing woods (at least 50 Australian species furnish valuable wood). Many Indian and African species furnish timber, gums, tanbark, catechu, and other products, and furnish host plants for the valuable lac insect (*Tacharia lacca*). The American *Acacia greggi* also furnishes lac. *A. farnesiana*, which is found in both the New and the Old World, is the famous "popinac" or "cassie" perfume plant so largely grown around Grasse in France.

Thus the farmer, the lumberman, the furniture maker, the stock raiser, the tanner, the perfumer, the chemist, and many others are interested in acacias, and the more useful species are properly recognized as being worthy of establishment over large areas, and of management on principles of forestry. The recognition of this fact has been notable during the last 10 years, because the best species of acacias are rapidly disappearing from their native countries, except where they have been intelligently protected and planted; and, further, because so many countries have successfully introduced acacia culture.

ACACIAS FOR SAND-DUNE RECLAMATION.

The acacias have great value as a ground cover, for dunes near the ocean, and for inland sand barrens, almost to desert conditions, since they will thrive with only a few inches of rainfall, provided it comes at such a time that the seeds can become rooted, and provided the temperature does not fall below 20° F. Where the average rainfall is not less than 20 inches and the summers are cool and the winters mild, almost any trees can grow if they get a start; what is needed in the first place, therefore, is some growth which will hold the drifting sands, binding them until a more stable soil, with some humus, is formed, and paving the way for valuable trees. This need is supplied by acacias.

Almost all west coasts present similar problems, not essentially different from those which have been successfully solved by Bremontier in France, and by Reventlot in Denmark.

The California dunes, the French *landes*, the Dutch *polders*, the Danish heaths, and the barrens of the Baltic coast of Prussia are all in the same category. Abroad the abundant use of the sea reed *Ammophila arenaria* is of first importance; but in the warmer regions of the globe the acacias can always follow the grasses. In some instances, if the acacias are freely used, they may entirely obviate the need for the preliminary grasses. In these warmer climates the low-growing acacias are much preferable to the broom and gorse so useful in more northern latitudes, while the larger acacias grow much faster than most other trees.

Abroad.

Africa.

The experience of several countries with acacia plantations near the shore emphasizes their desirability on such soils.

Cape of Good Hope.—The official reports of the conservator of forests, Cape of Good Hope Colony, South Africa, gives the results of extensive reclamation of sandy regions near the shore. For nearly 30 years these "blue books" have been crowded with information of interest to those who have to deal with the problem of fixing sands.

While acacias were first grown in South Africa for tanbark, firewood, and other uses, their value in making productive the enormous sand wastes was soon recognized. Such situations were extensively seeded, sometimes with acacias alone, and sometimes in combination with cluster pine (*Pinus pinaster*), the favorite conifer of the South African planter. The principal species were *Acacia leiophylla* Benth., (*Acacia saligna*, Wendl.), *Acacia longifolia* Willd., and *Acacia pycnantha* Benth., all of which yield tanbark, besides some of the larger wattles, such as *decurrens*, together with many of the lesser shrubby species. The climatic conditions are often more detrimental than those which prevail on the California sea coast, and the labor problem is certainly no more satisfactory.

Now that the plantations are well established, the seed from them and from other older plantations is gathered every year at small cost. In 1891 about 1,600 pounds of acacia seed were sown, or distributed to the public; the next year, 4,000 pounds, 1,963 of which were *A. leiophylla*. By 1898 the forest officers reported an annual sowing of 4,840 pounds of *A. leiophylla* seed and 4,360 of the shrubby *A. cyclops*. Summing up, not less than 20,000 pounds of acacia seed of various species were sown or distributed to planters in South Africa between 1888 and 1899.

Port Elizabeth.—In 1892, at Port Elizabeth, South Africa, 150 acres of drifting sands were reclaimed by the broadcast sowing of

A. leiophylla, cyclops, and *pycnantha.* Since the sand was very loose and fine, stakes interwoven with brush were first used to keep the sand from shifting, while the seeds were getting a start. The experiment was an entire success. The rainfall that year was about 16 inches. By 1896 more than 2,000 acres had been reclaimed at Port Elizabeth. In the choice of species it was planned that the smaller growth, such as *A. cyclops,* would bind the soil and enable the larger tanbark acacias to become established. During the South African war little was done to extend these plantations, but since then operations have steadily progressed.

The Port Elizabeth experiments demonstrated that broadcast sowing was not only feasible, but in this case seemed advisable. It costs from 4 to 6 cents a pound to gather acacia seeds from the bearing plantations. When the plantations were young the seed was drilled in at the rate of about 12 pounds to the acre. At this time, however, a much thinner sowing is usually considered better, and from 1 to 2 pounds only are sown to the acre, which would make the seed cost not more than 12 cents.

Port Jackson.—Acacias are being sown on drifting sands in South Africa in many other places besides Port Elizabeth, but the details of the planting are likely to vary with local conditions. At Port Jackson seed was sometimes sown in alternate rows with cluster pines, in some cases compartments or blocks of the plantation were entirely the one or the other. Again, rye or barley was sown thinly with the acacia or pine seed to give a quick binder and some shade. Ten years after planting the official report on these experiments states: "The sands have undoubtedly been fixed, and generally the trees have been doing well." The cost of these sowings ranged between $2.75 and $6 an acre. Wages were low, and it was practically all handwork, with but little use of labor-saving methods. The greatest expense was the filling in of gaps with nursery-grown plants, but this was seldom necessary.

ELSEWHERE.

Much additional evidence might be compiled from sand-binding in Natal, New Zealand, Australia, and the Mediterranean shores, but that which has been cited is sufficient to offer important suggestions for American practice. It has been conclusively proved that 16 inches of rainfall is ample; that it is an unnecessary expense to use nursery-grown plants; and that by using a mixture of shrubby and arborescent species, the larger tanbark and timber yielding trees can be started from the beginning of the operations. *Acacia cyclops* is valuable only for sand reclamation; the shrubby type of *A. longifolia* is quite as satisfactory. Even *A. longifolia* might be superseded by *A. leiophylla,* which resembles *A. cyanophylla;* it readily sends up shoots when cut down, and its bark contains from 30 to 35 per cent of tannin, which makes it a valuable commercial species. It is useful

also for firewood, as well as for fences and windbreaks. The *Acacia pycnantha* used in South Africa is the superb "golden" or broad-leaved wattle of South Australia, which yields one of the richest tanbarks in the world.

In California.

California has large areas of sand along the coast, more or less covered with beach plants, such as the abronias, lupins, and artemisias. Such sand areas have but little value, and have not improved in the past 50 years. These and similar areas in the Mojave region and the upper Salinas Valley can be readily reclaimed by the use of acacias, which can be selected not only for their sand-binding qualities but for their value as pasturage and as supplies of fuel wood and tannin. On such sand wastes the covering of shrubby acacias can be secured by sowing seed with the first rains in the fall. If the forage-yielding Australian "myalls" and "mulgas," such as *Acacia pendula, salicina,* and *aneura,* are chosen, they are likely to prove the most profitable crop that can be grown on such soils. *Albizzia lophantha* belongs with these as a shrub for browse. All of these species readily reproduce themselves, widening their extent along the seacoast, and will eventually produce a large amount of firewood.

As a matter of fact, acacias which have escaped from cultivation have become naturalized in many places along the California coast. There are thickets near the ocean between Watsonville and Santa Cruz, also near Morro, San Luis Obispo County, along the coast in Sonoma County, and likewise a few miles from Santa Monica. In a gulch near Carpinteria, south of Santa Barbara, there are self-sown seedlings and also large trees of *Acacia decurrens, melanoxylon,* and *longifolia,* which have grown from the stumps of older trees. Near old Ventura Mission there is the same adaptation of the Australian acacias to the California coast and foothills, even where they receive no care whatever.

In many cases the smaller acacias merely serve to fix the sand, and will properly give way to the larger acacias, to eucalypts, pines, casuarinas, and other timber trees. One large district which can be reclaimed in this way covers many square miles of coast in Monterey, San Luis Obispo, Santa Barbara, and other more southern counties. The same is true of large areas north of Monterey and about San Francisco, and of large inland areas where the sand is decomposed granite, adapted to *Acacia aneura* and *A. salicina.* Von Mueller recommends *Acacia excelsa* and the very shrubby form of *Acacia longifolia,* as valuable sand binders; both yield tanbark. According to the same authority, *Acacia giraffea* (Willd.), of South Africa, and *Acacia seyal,* of the Nubian Desert (neither of which has been tested in California), are especially drought resistant and have great economic value.

GOLDEN GATE PARK, SAN FRANCISCO.

The best evidence of the adaptation of nearly all of the Australian acacias to the sandy soil of the California seacoast, clear down to the ocean beach, directly exposed to heavy gales and dense salt fogs, is in Golden Gate Park, San Francisco, where they have been chiefly instrumental in making a magnificent park out of a waste area of drifting sand. The planting during the past 40 years furnishes the best record of the successful use of acacias in reclaiming sand dues that exists. At the present time there are superb thickets and copses of acacias, thoroughly established and naturalized, so that they require no cultivation. Not only that; they are extending themselves from year to year, within a stone's throw of the Pacific Ocean, and fixing the vagrant sands. Further inland similar thickets are changing to acacia forest, capable of yielding firewood and timber.

The planting began in 1870, and the stock used was chiefly for ornamental purposes. Trees from this first experiment are now standing in the older portions of the park—magnificent specimens of *A. melanoxylon* and *A. decurrens*. But even with this earliest plantation, some were set out on the sand hills to the west, simply as an experiment.

The westernmost 730 acres of this famous park consisted of great shifting dunes of sterile sea sand. The larger native growths were scattered evergreen scrub oaks and willows in the hollows between the barren sand hills. Often the dunes would drift over the willows and oaks and kill them. The struggle of these plants is clearly shown by the fact that lupin roots have been traced downward for more than 25 feet in the sands, while the roots of the willows have been followed for more than 100 feet from the main stems.

While many of the original acacias have been removed for one cause or another, this still remains a wonderful object lesson in acacia planting. Some trees have been taken out in the necessity for thinnings; others have had to give way to new driveways as they reclaimed the sands, thus making it possible to extend the cultivable portions of the park. The buildings for the Midwinter Fair of 1893 and the shelter tents for the homeless after the earthquake and fire of 1906 further diminished the thickets and groves, yet the arboretum contains the only California specimens known to the author of *Acacia discolor, A. capensis*, and *A. coccinea*.

These complete and long-continued tests indicate that the shrubby Australian acacias will cover sand dunes rapidly and efficiently and will furnish firewood in from 8 to 10 years from seed. While all this stock was nursery grown and transplanted, experiments in other places seem to indicate that seed can be sown directly on such sand slopes, and that the expensive nursery and transplanting practice,

while securing quicker results, is not really necessary. It should be kept in mind, too, that these plantations were not irrigated, and were left to shift for themselves.

At the very shores of the Pacific, south of the famous Cliff House, a place familiar to thousands of tourists, there are large low growths of acacia and albizzia, so close to the beach that the spray from the winter waves dashes over them. They are from 4 to 8 feet high, with close-matted roots and tops, which bind the sands and completely cover them. They are from 6 to 16 years old, and their stems are from 1 to 2 inches through. The albizzias begin to flower in November, and self-sown seedlings are numerous. They seem better able than the acacias to extend their foothold on the beach's extreme verge. The acacias bloom in February; they make few seeds in such an exposed situation, though farther inland they seed well.

A little farther east and more inland, at about a thousand feet from the ocean, are more acacias, principally *Acacia longifolia*, growing among and over the sand hills, and though these are no older than the beach thickets they are from 8 to 12 feet high, because they are more sheltered and in less saline soil and atmosphere. A very large area which was hopelessly barren has been rendered attractive by the acacia copses. There are a few sand willows and pines, but the bulk of the growth is of planted and self-sown acacias.

Still farther east, nearly half a mile from the ocean, but still on land which was formerly sand dunes, the acacias are somewhat older and give each other good protection. These are from 20 to 30 feet high, with stems from 10 to 18 inches in diameter. Like all the others in the sand hills, these trees never received any artificial application of water. They were set out during the rainy season from seed boxes when only a few months old, and were then left to fight their own battles. In many cases the little trees grew from 3 to 5 feet during the first spring.

In November some of the acacias on the sunny sides of the dunes show bloom, and by the middle of January the whole expanse is golden with blossoms. This is two weeks ahead of the same species on the beach.

The mixed plantations along railroad cuts in and near Golden Gate Park and in some of the older groves where good soil has been spread over the sand are now large and thrifty, fairly deserving the name forests. Individual specimens are 24 inches in diameter and are fit for timber.

There has always been a struggle between the sand and the vegetation, though in the end the acacias seem to be able to fix the soil, even though they have been temporarily killed back. Where the

sand has drifted in over the tops the trees have sprouted again from below, and have formed impassable thickets. These close clumps on pure sand do not seem able to grow higher than from 20 to 25 feet, but even this far surpasses the native scrub oak and willow. As the park reclamation is made complete, however, and richer soil spread out on the sand, *Acacia decurrens* and other large species immediately begin to grow sturdily, and age for age are as handsome and thrifty as those anywhere else in California.

The especial value of these experiments upon California sand dunes is the proof it gives that useful and ornamental plantations can be made in such places. The natural desirability of residences on or near the seashore is greatly increased if such homes can be sheltered by groves and thickets. Acacias not only furnish these groves, but help to retain the soil, furnish firewood, and, in the end, timber and tanbark. Nearly all of the acacias are beautiful in leaf and flower and graceful in their growth. Along the California coast, therefore, as on that of the Mediterranean, they should be extensively planted.

Correlating the Golden Gate Park and the South African experiments, species which seem most desirable for American plantations, for rapid reclamation and maximum profit are *A. pycnantha, decurrens, leiophylla,* and *longifolia* sown in combination with shrubby species which will give way when the sands are fixed and forest conditions established. The shrubby form of *A. longifolia* is the variety *sophoræ,* the spreading coast wattle; the tall form which might follow this is the Sydney golden wattle, the bark of which yields from 15 to 20 per cent of tannin, used chiefly for sheepskins. When the sand-dune area has become well covered with *A. pycnantha* and *A. decurrens* it is a tanbark proposition. If the object is mainly shelter and beauty, with the production of some tanbark as a secondary consideration, the final species would well be *A. cyanophylla* (blue wattle), *A. decurrens* var. *mollis* and *A. baileyana,* as well as *A. pycnantha.* All these thrive near the seashore and on light soils. *Acacia longifolia, cyanophylla,* and *pycnantha* are the best ones for inland localities up to an elevation of from 2,000 to 2,500 feet in southern California, though the amount of frost rather than the elevation furnishes the deciding factor. In this list, all except *A. baileyana* yield tanbark. A purely ornamental plantation on the seacoast might include several hundred species, and would be exceedingly attractive.

Because of its rapid growth in California and its value as a shelter and a sand binder *Albizzia lophantha* should be extensively planted. It is one of the best species for obtaining a quick sand cover, and reproduces itself faster than any of the true acacias. It is particularly advantageous as the extreme advance guard of acacia plantations nearest to the shore.

ACACIAS FOR TANBARK.

At the present time the chief commercial value of acacias seems to be for tanbark, although even with the tanbark species there are important by-products. The tanbark industry is bound to increase in importance; tanners are searching farther and farther for the materials they need, especially since, for the treatment of heavy, high-grade leathers, no real substitutes for the best vegetable tans have yet been discovered.

Important Tanbark Species.

All of the leading tanbark acacias are from Australia and are generally known as wattles. This term is of local origin. Early settlers in the Australian bush made huts by weaving or wattling green branches together, and since acacias were most often used the name wattle has since been applied to the strong-growing species. In his time Von Mueller designated only five acacias as wattles, though he names many others as yielding tanbark. Dr. Maiden applies the term to more than 30 species whose bark he has tested. It is evident, however, that while many will yield bark worth using, when the tree is cut for timber (this is true of all the more valuable timber species) only *A. pycnantha* and the best varieties of *A. decurrens* justify planting for tanbark alone. *Acacia decurrens mollis* and *decurrens normalis* are the largest and best of the *decurrens* forms, and are stronger growing trees than *A. pycnantha*, but the latter yields the richer bark. These trees, then, are all that are worth serious attention for tannic acid. *Acacia melanoxylon, decurrens, dealbata, longifolia,* and others whose timber is of first importance yield tanbark only as a by-product.

The two *decurrens* varieties (*Acacia decurrens mollis* and *A. decurrens normalis*) may be taken as the typical tanbark acacias. Von Mueller's statement in 1882 of the value of their bark can scarcely be improved upon:

> It varies in its content of tannin from 30 to 40 per cent in bark artificially dried. One and one-half pounds of the bark give 1 pound of the leather, while 5 pounds of English oak bark are requisite for the same result. Melbourne tanners consider a ton of black wattle bark sufficient to tan 25 or 30 hides; it is best adapted for sole leather and so-called "heavy" goods.

Acacia Pycnantha.

Acacia pycnantha is now strongly recommended by all who have studied tanbark production from this genus. The Kew Bulletin of 1893 especially urges the planting of *A. pycnantha*. Naudin says that the bark of this species has been known to contain 46 per cent of tannic acid, and that ordinarily it yields from 35 to 40 per cent. According to Von Mueller it is "second perhaps only to *Acacia*

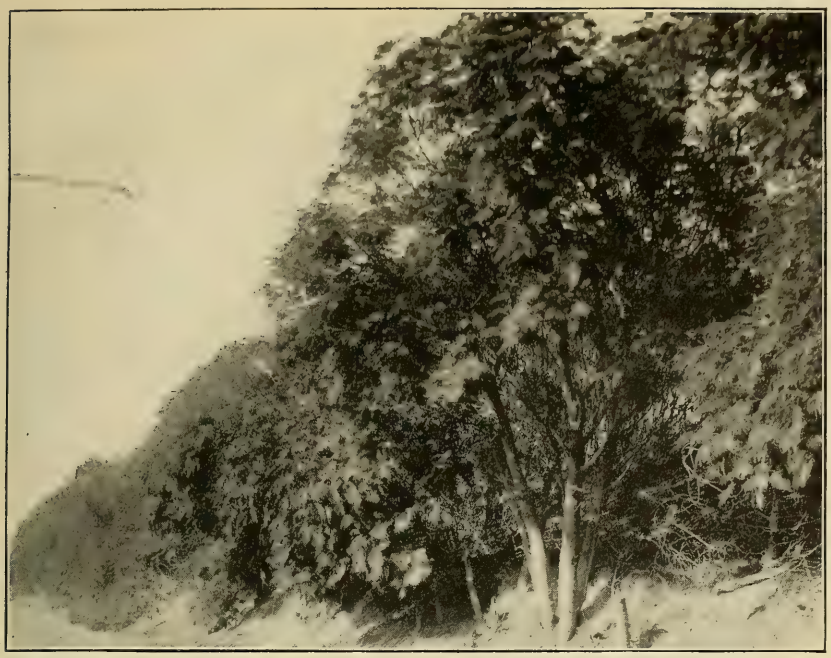


FIG. 1.—DRIFTING SANDS HELD IN PLACE ALONG A CAR TRACK BY A PLANTATION OF ALBIZZIA LOPHANTHA, NEAR THE CLIFF HOUSE, SAN FRANCISCO.

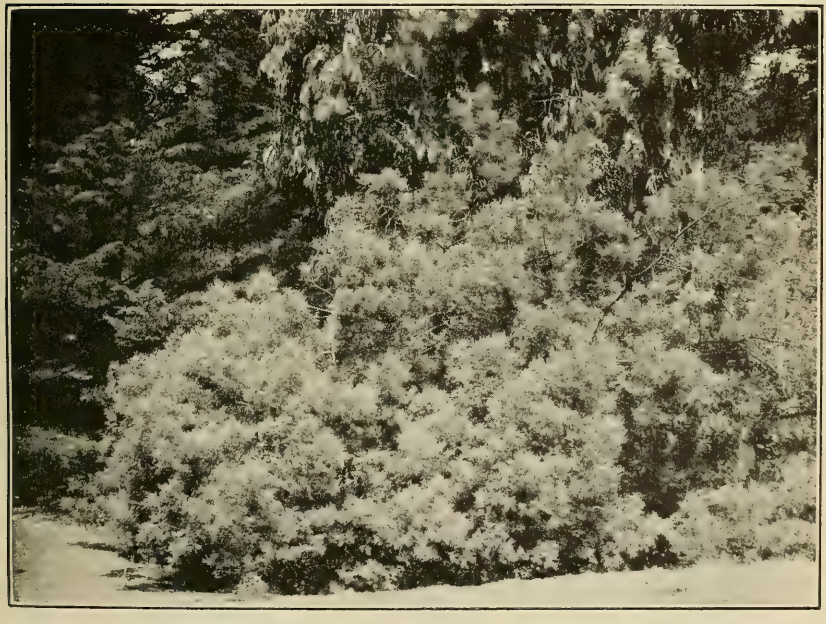


FIG. 2.—A MASSED PLANTING OF ACACIA LONGIFOLIA IN THE RECLAIMED PORTION OF GOLDEN GATE PARK, SAN FRANCISCO. BLUE GUM, EUCALYPTUS GLOBULUS, AND MONTEREY CYPRESS IN THE BACKGROUND.

FIG. 1.—ACACIA LONGIFOLIA FROM SELF-SOWN SEED, BERKELEY, CAL.

FIG. 2.—YOUNG GROWTH STARTING FROM A BROKEN AND SCARRED TRUNK OF ACACIA DECURRENS MOLLIS, BERKELEY, CAL.

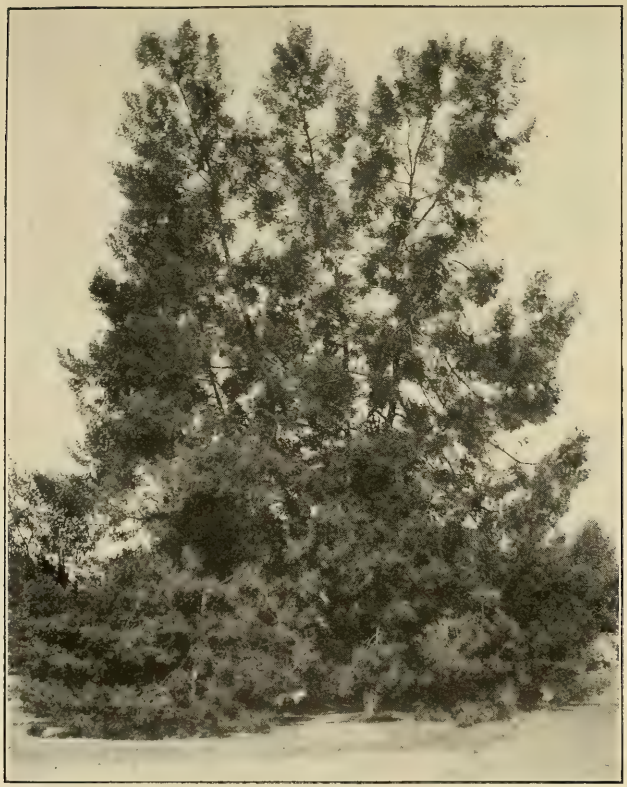


FIG. 1.—A FIVE-YEAR-OLD ACACIA DECURRENS NORMALIS FROM SEED, POMONA, CAL.

FIG. 2.—A SPECIMEN OF ACACIA DECURRENS NORMALIS, 20 YEARS FROM SEED, SANTA MONICA, CAL.

FIG. 1.—TANBARK ACACIAS OF SANTA MONICA, 20 YEARS OLD AND FROM 30 TO 40 FEET HIGH. ACACIA DECURRENS MOLLIS AND DECURRENS DEALBATA.

FIG. 2.—TANBARK ACACIAS (DECURRENS MOLLIS) AT BERKELEY, CAL.

decurrens in importance for its yield of tanner's bark; the quality of the latter (*A. pycnantha*) is sometimes even superior to that of the black wattle, but the yield is less." Dr. Maiden says it is "one of the richest tanning barks in the world; a richer may exist, but I do not know of it." The sample bark that he analyzed in 1880, by Lowenthal's improved process, showed tannic acid 46.47 per cent, extract 74.07 per cent. This was, of course, an extremely rich sample. Thirteen samples from the Government farm at Bellair, South Australia, taken from trees at various ages and grown on different soils, ranged from 28.5 to 38.5 per cent tannic acid and from 57.75 to 68.35 per cent extract. The trees were from 3 to 7 years old; the soils were light and shallow and mostly on a bedrock of hard sandstone.

This is the true golden wattle of Von Mueller, and when in bloom it is strikingly attractive. It is considerably smaller than any of the *A. decurrens* forms; hence it may not yield as much bark per acre as *Acacia decurrens mollis*. But the trees can be set closer together, and the quality of the product is unsurpassed.

ACACIA DECURRENS DEALBATA.

Good barks of *Acacia decurrens dealbata*, or silver wattle, contain about 25 per cent of tannic acid. In some situations it grows faster than the normal *A. decurrens*, and when full grown always forms a stately tree. It requires rich moist soil and a frostless locality. On river banks in Australia it reaches a height of 150 feet; in California the largest recorded specimen is 90 feet high and 2½ feet in diameter. Several considerations militate somewhat against its planting. In the first place, it will hardly pay to plant it where the more productive *A. pycnantha* and *A. decurrens* will thrive; and it is not frosthardy. The root system of *A. dealbata*, like that of *A. melanoxylon*, is mainly at the surface, and the trees are easily blown over.

ACACIA MELANOXYLON.

The appearance of *Acacia melanoxylon*, the black wood of southeastern Australia, is very different from that of the feather-leafed acacias. It belongs, with *Acacia longifolia*, *A. pycnantha*, and most of the Australian species, to the wonderful phyllodinous acacias. With these the true leaves are suppressed, or nearly so, and the flattened leaf-stalks (phyllodia) perform the functions of leaves. The first foliage from seedlings of any of these species are delicate, feathery, bipinnate leaves; but the leaf-stalk soon broadens, lengthens, and hardens, finally changing to a leathery phyllodium. Sometimes a few of the true leaves will persist for a long time at the

terminals of the former leaf-stalks, and occasionally they may show on the younger growth.

The tree is less valuable for tannin than for timber; but a tree so large and rapid-growing, the bark of which has a 15 or 20 per cent tannin content, should not be neglected in calculations for tannin production, especially since the development of the manufacture of tannin acid extract. *A. melanoxylon* properly belongs to moist and not frosty situations, and its roots are surface feeders. When young it is particularly susceptible to drought, and will die on soil the least bit arid; moreover, it succumbs readily to desiccating winds, such as the drying northers of California. Von Mueller reports it as being hardy (with some forms of *A. decurrens*) on the Isle of Arran, Scotland. This does not, however, prove the hardiness of the tree so much as it does the variation of local climatic conditions, since *A. melanoxylon* has been injured by frost (7° F.) at Chico, Cal. It is useless to plant it in arid uplands, but its resistance to trying city conditions and its power of utilizing sewage make it of value as a street tree.

Tanbark Acacias Abroad.

Australia and New Zealand.

In Australia acacias have been utilized for tanbark for a long time, the natural supplies being drawn upon exhaustively and the artificial culture of acacias consequently neglected, since there was an abundance of tan-yielding species on hand.

Some 35 years ago, however, Baron von Mueller called attention to the rapid depletion of the natural supply, and from that time a voluminous and important official literature upon acacias and acacia culture grew up. Since 1875 these reports have aroused general as well as local interest in the planting of the species for tanbark.

The three earliest and most careful estimates of planting costs, based upon actual experiments in 1878, 1884, and 1889, give, respectively, the following figures:

(1) *Acacia decurrens*, 100-acre basis, rented at $1.50 an acre a year, 400 trees planted per acre:

Aggregate sales of bark, first 8 years, 1,215 tons	$23,290
Aggregate expenses, including interest	7,270
Profit	16,020

(2) *Acacia pycnantha*, 100-acre basis, bought at $15 per acre; 1,200 trees to the acre:

Aggregate sales of bark, first 7 years, 500 tons	$12,000
Aggregate expenditure, first 7 years, including interest	8,700
Profit	3,300

(3) *Acacia pycnantha*, 100-acre basis, sowed broadcast and thinned to 1,200 trees to the acre; land rented at 8 cents an acre a year, under the provisions of the wattle-culture act passed in Victoria Colony in 1889:

Aggregate sales of bark, first 7 years, 642 tons	$23,120
Aggregate expenditure, first 7 years, including interest	7,360
Profit	15,760

While these estimates differ considerably, based as they are upon various crop prices, land values, production costs, and yields, they are still suggestive. In fact, the only point in common between the three plantations was that in each case there was good preparation of the soil and careful cultivation.

The Queensland Agricultural Journal recently reported that in Auckland, New Zealand, an otherwise useless tract of land of about 4,500 acres planted to *Acacia decurrens* gave the following results:

Aggregate sales of bark, per acre, first 8 years	$142
Aggregate expenses, per acre, first 8 years	70
Profit (not including 5 cents per acre per year, and not including interest)	72

In South Australia, on the unproductive "fern hills" of white sand and on dry limestone ridges, acacias grow well. Such land can be rented at less than 4 cents per acre a year, and ought to yield from $70 to $80 per acre at the end of 8 or 9 years. Better soils will give proportionately better yields, but the striking thing about the New Zealand and Australian reports is the unanimity of opinion as to the value of wattles upon poor soils.

SOUTH AFRICA.

Thirty years' experience with tanbark wattles in Cape Colony, Natal, and other places in South Africa has been quite as interesting as the experience with sand-binding acacias.

Originally introducing *Acacia saligna* for tanbark, Cape Colony made strenuous efforts to plant large areas. In some districts material was needed for huts, fences, and fuel, and this made a demand for small stuff which would grow rapidly. This demand led to the planting, in some instances, of as many as 20,000 acacias to the acre, the plantations being thinned out at the end of the fourth year and the wood and bark of the trees removed in thinning being sold. In some plantations trees were set in rows 4 feet apart or alternated with cluster pines. By 1890 about 150 tons of bark were marketed, and in 1891 nearly 2,500 tons, partly from government forests and partly from trees belonging to settlers.

As soon as the superiority of other tanbark species was recognized, *Acacia saligna* was dropped and better species planted on an exten-

sive scale. In 1896, for example, 494,873 *Acacia decurrens* were set out in one of the Crown forests. At another place 10½ acres were sown broadcast with this species, and on one-half acre seed was drilled in.

Tanbark acacias have been planted more or less extensively, especially since the war in the Transvaal. The assistant conservator of the Transvaal forests published a full report on acacia culture in the Transvaal Agricultural Journal for January, 1910. In this he states that after extensive trials *Acacia decurrens* (varieties *normalis* and *mollis* or *mollissima* and *Acacia cycnantha*) are found to be the best sort, with the *decurrens* type in the lead. Photographic illustrations in the report show dense, mature wattle plantations and also the processes of stripping and preparing the products for market. He states that wattles can be grown anywhere in the Transvaal, but most successfully at elevations of from 3,000 to 5,000 feet on the high plateaus, with a preference for eastern slopes. The most suitable soil is a light red or chocolate well-drained loam. The annual rainfall is from 30 to 40 inches and there are no extreme frosts. Acacia culture is spoken of as a most promising industry.

NATAL.

Probably the most suggestive and interesting chapter in the history of commercial planting of acacias is furnished by the rise of the wattle industry in Natal during the past 30 years. The yield from cultivated trees surpasses that which has been obtained from natural growth, the two leading forms of *Acacia decurrens* being the most valuable kinds, with *mollis* as the hardier variety. In 1886 the acacia tanbark export was valued at $55. By 1902 the exports had risen to $370,000 worth, and this does not include any report of material used for local consumption. Several companies planted 3,000 acres and some are adding at the rate of a thousand acres a year. It is claimed for the industry that it yields a high rate of interest without high-priced management and utilizes soils unsuited to general cultivation. In 1906 Natal had more than 30,000 acres in acacia plantations and at the present time this area is more than doubled. Mr. David G. Fairchild, in charge of Foreign Seed and Plant Introduction, United States Department of Agriculture, states that the black wattle most generally planted has been *Acacia decurrens mollissima*.[1] He notes that a few years ago wattle bark reached the price of $82.79 a ton and this high price greatly stimulated planting. What is known as the Townhill plantation, 2,400 acres, situated 2,700 feet above sea level, was begun in 1892. The topography was rolling hills and the soil a light red loam with sand, gravel, and clay. The tract was

[1] Miscellaneous Papers, Bulletin 51, Bureau of Plant Industry, U. S. Department of Agriculture.

grass covered and therefore required no clearing. Rows were marked at 12 feet apart and the seed was hilled 6 feet apart in the rows. Corn was grown between the rows for the first two years in order that its yield would help to reduce expenses. At 10 years old the trees were 10 inches in diameter.

All the work on this 2,400 acres is done by 60 natives, who peel, cut, and dry the bark, stripping it at any season that it will peel easily. They use drying sheds of galvanized iron, each one of which holds about 6 tons of bark.

The gross receipts from 10-year-old trees at the price of $32 per ton, when Mr. Fairchild made the study, was from $161 to $193 an acre. The operating cost for harvesting the product was $7.30 a ton or $43 an acre. The 10 years' care of the land, the cost of the land—in this case only from $5 to $6 an acre—and interest were said to be covered by the sale of the wood for mine props, fuel, and small timber. No replanting has been necessary, since thousands of seedlings come up and cover the ground.

Another valuable publication on acacias in Natal has been furnished by Mr. T. R. Sims;[1] but the most complete publication which covers the entire industry in 10 countries is the third edition of Dr. Maiden's "Wattles and Wattle Barks."

NORTH AFRICA.

Johannes Paessler, of Levertechn, published in 1910 a paper on acacia bark grown in North Africa, in which he speaks of *Acacia decurrens*, *decurrens mollis*, *decurrens dealbata*, *pycnantha*, and *penninervis*. According to his report only the best species are planted and the tannin yield, which was less than 30 per cent, is now increasing. *Acacia decurrens* in German East Africa, at an elevation of from 4,000 to 4,500 feet is ready for gathering at five years, and yields a bark of higher tannin content than that from Natal. At Freiburg Station 260 bark samples were analyzed by the filter method since 1901, with the following averages:

	Per cent.
Tannins	33
Nontannins	8.5
Insolubles	43
Water	14.5

There is a smaller proportion of nontannins to tannins in acacias than in the domestic barks, such as oaks. The sugar content is very low, which gives the acacias only slight acid-forming power. Ground acacia bark, according to this report, in Germany in 1910 cost $55 a ton, which makes the tan worth about 8½ cents a pound.

[1] "Tree Planting in Natal," Chapter 9: "The Black Wattle Industry," Bulletin 7 of the Natal Department of Agriculture, Pietermaritzburg, 1905.

HAWAII.

Prof. Jared C. Smith has made a full and careful report of experiments with black wattles in Hawaii.[1] In this he states that acacias have been grown in the Hawaiian Islands for about 40 years, thriving on heavy soils with a rainfall of from 80 to 150 inches. The remarkable fact in connection with this exceedingly heavy rainfall is the adaptability of the acacias to various conditions from drought to deluge, and points to their possible use in such locations as the Colorado River bottoms and along the Gulf coast.

Six acres of 13-year-old trees yielded $254.84 per acre. The bark brought about $139 (5.9 tons at $23.31 per ton). The wood sold for fuel yielded about $114.

According to Mr. Smith, one man with good tools and a team can take care of 250 acres of black wattles with ease when it has once been sown and thinned. "One pound of good seed should plant 10 acres." This illustrates scientific progress, since many planters have been in the habit of sowing 5 or 10 pounds to the acre. Yet *Acacia pycnantha* has about 23,800 seeds to the pound; *A. normalis*, about 28,500, and *mollis* 38,500. The present Australian practice is to sow from one-third of a pound to a pound of seed an acre, but since 1,200 trees is an abundant stand and 800 is better, a pound of good seed should sow 10 or more acres. In the famous Tantalus acacia plantation in Hawaii, the trees of 13 years vary from 6 to 18 inches. A 10-year-old tree would yield 100 pounds of green bark, which is equal to 50 pounds dry. The best trees yield as much as 200 pounds.

TANBARK ACACIAS IN CALIFORNIA.

While there are no commercial plantations of tanbark acacias in the United States, the leading tanbark acacias have long been grown at the California Experiment Station at Berkeley and at various substations. Their product has been analyzed and compared with that from the California oaks and from canaigre (*Rumex hymenosephalus*). In the bulletins of the California Experiment Station and of the Federal Forest Service [2] attention has been called to the rapid disappearance of California tanbark oak (*Quercus densiflora*), the tannin from which has given high reputation to California-tanned heavy leathers. The constantly increasing cost of the bark has been noted and at the same time the deterioration of its quality, since mere bushes and saplings are now being stripped for the thin young bark, incomparably inferior to the old thick bark from the boles of mature trees. The necessity of securing a supplement to or substitute for

[1] Bulletin 11, Hawaiian Experiment Station, 1906, "The Black Wattle in Hawaii."

[2] Bulletin 75, Forest Service, U. S. Department of Agriculture, California Tanbark Oak, by Willis Linn Jepson, issued Sept. 20, 1911.

this source of tanning material has been recognized for some time; the planting of wattles would seem to offer a solution for the difficulty.

POSSIBILITIES OF GROWTH.

There are enough trees in California to furnish seed; and the growth of individual trees has already demonstrated the fact that tanbark acacias should be successful over large areas. On the Pacific coast and in the Southwest there are many districts well adapted to tan-yielding acacias; and there should be a market not only for the bark but for fuel wood after the bark is removed. Even where isolated trees suffer from frost, groves of trees sheltering each other will not be subject to the same damage. *Acacia pycnantha*, even when small, has withstood the winters of Cholame Valley, Monterey County, in a district where peach, cherry, and grape crops have been lost through late frosts.

While the amount of rainfall which acacias require seems not to have been determined, it is generally assumed that 16 inches a year is the minimum for *Acacia decurrens*. Yet deep-rooted saplings will thrive on much less. The reports of the University of California show that in the drought years of 1897, 1898, and 1899 acacias of the leading tanbark species grew well with rainfall of from 4.8 to 8 inches. In Los Angeles County young trees set out in the spring of 1897, and thus subjected to three successive drought seasons, made growths of from 4 to 6 feet in height a year, and in 1911 were 2 feet in diameter. These and other instances justify the belief that some of the best Australian acacias will thrive in America under almost desert conditions. If they can be made to supplant large areas of chaparral they will maintain a protective covering for the soil and produce in addition a profitable crop.

The increasing demand for tanbark ought to direct attention to these drought-enduring wattles. In California the native oak has advanced in price from $6 per ton in 1870 to $48 at the present time. Bark cutters are now forced to seek the most remote and rugged canyons in Mendocino, Humboldt, and Del Norte Counties, and sometimes carry out the bark on pack mules. In the Mendocino forests, once thought to furnish a practically inexhaustible resource, the writer has seen the bark cutters stripping trees only 3 inches in diameter.

California has a large investment in the tanning industry, and California leathers are shipped to all parts of the world, so that the disappearance of the main source of tannin supply becomes a serious problem.

It should be possible to produce wattle bark for market on low-priced land from cheap home-grown seed. While it is useless to

expect to rent land in America at the Australian price of 4 cents an acre a year, there is nevertheless cheap and suitable land in California and the Southwest.

TANNIN CONTENT OF CALIFORNIA BARKS.

The first acacia barks analyzed by the University of California were those of *Acacia decurrens mollis*, *A. decurrens dealbata*, and *A. pycnantha*. In the report upon these barks [1] it was shown that the California-grown bark of *mollis* was twice as thick as that of *dealbata* of the same age and that it yielded about twice as high a percentage of tannin. This agrees very nearly with comparisons made upon barks grown in Australia and in Algeria. The actual tannin contents of these three barks grown at Berkeley were as follows:

	Per cent.
Acacia decurrens mollis	48.6
Acacia decurrens dealbata	24.8
Acacia pycnantha	46.8

Dr. Hilgard states that these tannin determinations were made by the permanganate method, repeatedly checked by the gelatin or hide-strapped method, with but trifling differences in the results, so that the figures fairly represent what hides will take up.

One of the trees, 13 years old when cut for these experiments, was 12 inches in diameter at 3 feet above the ground, and 40 feet high.

It will be observed of these analyses that California-grown *A. pycnantha* bark, contrary to Australian experience, did not exceed *mollis* in richness of tannin content. Later analyses seem to confirm this general fact: That *A. decurrens normalis* and *mollis* are proportionately richer in tannin when grown in California than when grown in Australia. As yet, however, the quantity of bark which has been produced is not sufficient to settle this interesting and important point, though everything points to the desirability of both of these forms of *Acacia decurrens* for planting in California, particularly in the Coast Range, where the bark so far tested has been grown.

Another report [2] gives some interesting statistics about the plantation at Santa Monica, which has been under charge of the University of California since 1894. This report states that *Acacia decurrens* and *A. pycnantha*, 25 months from seed (20 months planted in the field), have grown twice as rapidly as the same species mentioned in Australian reports. Many trees of this age had attained a height of 16 feet and the very poorest were 2 inches in diameter and 9 feet high. Mr. Lyon estimated that at 4 years of age such a plantation would yield a crop of bark equal to that of 7 or 8 year old Australian groves; that is, from 80 to 90 pounds of bark to a tree.

[1] Report of Dr. Hilgard, Jan. 23, 1884.

[2] Third Annual Report of the First Board of Forestry of California; Chapter on Acacias, by W. G. Lyon, State Forester, 1890.

Fig. 1.—Twenty-Year-Old Acacia melanoxylon, 40 Feet High and 16 Inches in Diameter, Grown on Poor, Gravelly Soil at Santa Monica, Cal.

Fig. 2.—Twenty-Year-Old Acacia decurrens dealbata, Near Niles, Cal.

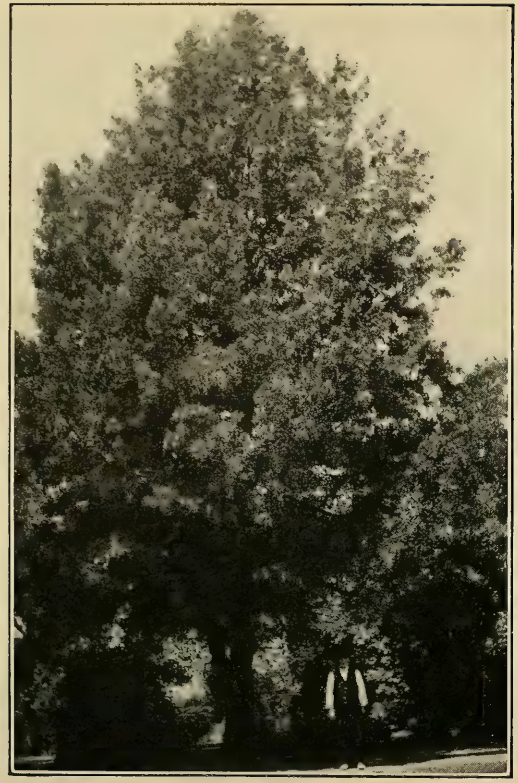


FIG. 1.—TWENTY-YEAR-OLD ACACIA MELANOXYLON ON A FARM NEAR NILES, CAL.

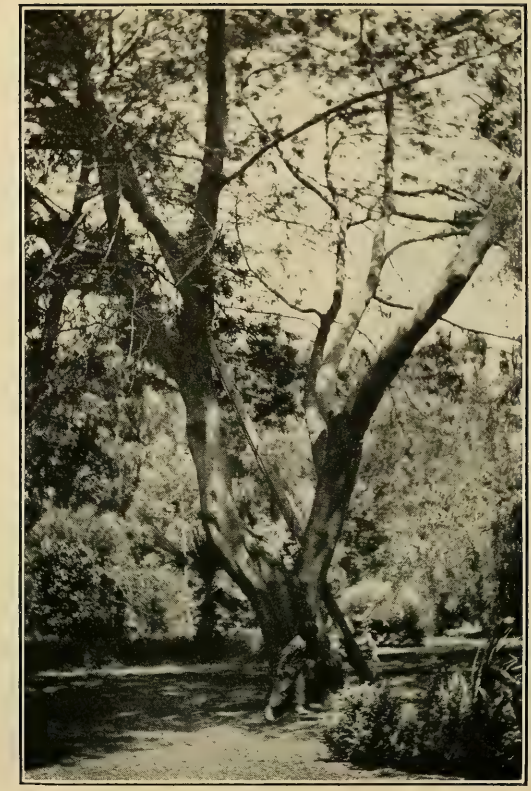


FIG. 2.—ACACIA DECURRENS NORMALIS ON A FARM NEAR NILES, CAL.

There are reports of trees of *Acacia decurrens mollis* in southern California which when 4 years old were 30 feet high and 8 inches in diameter.

A complete analysis of the tanbarks grown at Santa Monica Forest Station, made in June, 1898, by Mr. George Colby, of the California Experiment Station, gives the following results:

	Water in air-dried bark.	Tannin in air-dried bark.	Water-free substance.
Acacia decurrens normalis:	*Per cent.*	*Per cent.*	*Per cent.*
Bark, main tree	6.53	42.48	45.83
Bark, branches	8.28	36.57	39.98
Bark, large roots	5.28	31.35	33.10
Acacia decurrens mollis:			
Bark, main tree	7.60	45.98	49.76
Bark, branches	8.08	42.98	46.66
Bark, large roots	7.89	32.37	35.18
Acacia pycnantha:			
Bark, main tree	9.32	41.80	46.09
Bark, branches	8.67	38.66	42.34
Bark, large roots	7.10	47.02	50.58

Two points are brought out by these analyses: *Acacia pycnantha* alone showed a higher proportion of tannin than a bark with a large root, although this fact is likely to be true of the various forms of *Acacia decurrens*. The superior value of *Acacia decurrens mollis* is plain. All of these barks gave good results in practical tests by tanners. It should be stated that these results were not obtained from commercial plantations, and that notwithstanding the figures which were presented so many years ago by the University of California, no commercial plantations were set out. The principal reason for this was that at that time the demand for tanbark in California was sufficiently supplied by tanbark oak, which was then abundant; moreover, public attention had not been then directed to the possibilities of forest planting for timber, tanbark, and other products.

ACACIAS FOR TIMBER.

Throughout the world there is evidently an increasing demand for hardwoods. In the eastern United States, which probably furnished the best supply of hardwood lumber that has ever been known, the diminution of the supply has already caused readjustments in several industries which have depended upon it.[1] The foresters of South Africa, Algeria, and Australia are planting tons of acorns to grow future hardwood forests. California in particular, rich in conifers, has no hardwoods of commercial importance, and the introduced eucalypts present many difficulties in utilization.

Principal Timber Species.

Many of the acacias furnish useful and valuable timber and are not only beautiful in grain but durable in contact with the ground. Even

[1] Circular 116, Forest Service, U. S. Department of Agriculture, the Waning Hardwood Supply.

the smaller species have high value for tool handles, for furniture, and for various other useful and ornamental objects. Some of the best species yield very hard, heavy, close-grained, tough timber that is fairly comparable to walnut and rosewood.

Acacia melanoxylon.—Wherever it thrives *Acacia melanoxylon* is considered the most valuable of the timber acacias. The tree grows very rapidly and reaches a height of from 80 to 90 feet and a diameter of 3 feet. Von Mueller reports its strength as surpassing that of kauri and approaching the best American white oak. In his experiments a weight of 2,296 pounds is required to break a piece of *Acacia melanoxylon* 2 feet long and 2 inches square, supported at the ends. The Victorian Timber Board, in 1884, found that 956 pounds were required to break test pieces 1½ inches and 6 feet between bearings. This wood averaged 53 pounds per cubic foot, but its more usual weight is from 41 to 48 pounds. The tensile strength of good samples is reported by Mr. Campbell at an average of 27,500 pounds per square inch.[1] The Kew Bulletin for May, 1899, states that the timber of *Acacia melanoxylon* is sound and easily worked; that its prevailing color is brownish, striped with red and light golden, which made an "exceedingly beautiful" combination in the best specimens. The report adds that such a wood may be used to advantage in place of the best Honduran mahogany, and that some lots, while less ornamental, "are excellent for high-class turnery." Maiden says:

> Hard and close-grained; much valued for furniture, picture frames, cabinetwork, fencing, bridges, railway and other carriages, boat building, tool handles, gunstocks, naves of wheels, crutches, parts of organs, pianofortes, billiard tables, etc.; almost equal to American walnut; excellent wood for handling under steam; largely used for oil casks.

It is also used for oars, buggy shafts, bookcases, tables, and cabinetwork of various kinds.

Growth notes on *Acacia melanoxylon* in California show clearly its importance as a timber species. About a hundred tree measurements in different portions of the State, from Shasta south to San Diego, taken at various times between January, 1910, and June 1, 1913, show that on average soils, with an annual rainfall of from 15 to 30 inches, and without irrigation, trees 20 years old average 40 feet in height, with a stem diameter of 18 inches.

Some of the single measurements of older trees are as follows:

At Hotel Del Monte, Monterey, a tree 30 years old measured in May, 1913: Height, 70 feet; diameter at 4 feet from the ground, 2 feet 8.4 inches. At Golden Gate Park, San Francisco, a tree 35 years old, in almost pure sand, measured winter of 1912–13: Height, 60 feet; diameter, 4 feet from the ground, 2 feet. Another, 36 years old, on better soil: Height, 75 feet; diameter, 4 feet from

[1] Proceedings of the Royal Society of Victoria, 1879.

ground, 2 feet 8 inches. At Niles, a tree 46 years old, on side valley soil, 76 feet above San Francisco Bay, top broken off at height of 65 feet, though the tree had been about 80 feet high, diameter 2 feet 6 inches. Near Alvarado, a tree 45 years old, on rich soil, 85 feet high, diameter, breast high, 3 feet 9 inches.

All portions of the Sacramento and San Joaquin Valleys appear well adapted to the growth of *Acacia melanoxylon*. At the Chico forestry station and elsewhere it showed no injury, except to the young tips of the top branches, during the low temperature of the coldest seasons between 1890 and 1913 (16°, 14°, and 12°). Large eucalypts were killed to the ground by these frosts.

The bark of this species yields about 11 per cent of tannic acid, which could be utilized profitably when the timber is cut by concentrating it in the form of an extract. The inner bark, as with some other acacias, yields a valuable bast or fiber material.

Acacia decurrens group.—There is little difference in the woods of the three leading varieties of the *Acacia decurrens* group (*normalis*, *mollis*, and *dealbata*), but the last two grow more rapidly and attain the larger size. *Dealbata* trees have been measured and found to be 100 feet high and 4 feet in stem diameter. This variety has been naturalized in southern India since 1840 and extended over a large area. The timber of all three varieties is moderately hard, light brown in color, easily worked, and strong; it is used by coopers and house builders; it is valuable for posts, for rustic work, for mine props under ground, and for fuel. Its weight is about 47 pounds to the cubic foot.

Acacia decurrens normalis and *mollis* are more generally planted than *dealbata*. Von Mueller gives the weight of their timber at from 45 to 48 pounds per cubic foot. Maiden reports that three slabs of *normalis* at the Technological Museum, seasoned for more than 25 years, weighed, respectively, 52, 53, and nearly 63 pounds per cubic foot.

Other timber species.—Many other species of acacia yield valuable timber. Of those listed, all have been grown in California.

Acacia acuminata.—Stem diameter, 12 inches. Wood strong and very hard, red-brown in color, and durable. Has a raspberry-like scent.

Acacia aneura.—Stem diameter, 10 to 12 inches. Exceedingly hard and strong wood of a dark-brown color.

Acacia arabica.—Stem diameter of 2 feet. Wood used for boats, water wheels, and many implements, on account of its strength and durability. The tanbark is a by-product of this species. (See pl. II.)

Acacia armata.—Shrub or small tree. Wood beautifully grained and durable.

Acacia aulacocarpa.—Wood heavy, hard, tough, light red. A cabinet wood.

Acacia bidwilli.—Stem diameter, 18 inches. Timber hard. Takes a good polish.

Acacia binervata.—Stem diameter, 12 inches. Wood close-grained, tough, light, called "hickory." Used for ax helves.

Acacia cunninghami.—Stem diameter, 12 inches. A dark-colored and heavy cabinet wood.

Acacia doratoxylon.—Stem diameter, 12 inches. Wood hard, tough, heavy, durable; very useful timber for buggies, whiffletrees, wagon poles, and furniture.

Acacia falcata.—Stem diameter to 12 inches. Spoken of as another hickory. Wood heavy, hard, and tough; yellow and light brown; easily bent into sharp curves by carriage makers. Used also for stock-whip handles.

Acacia farnesiana.—Stem diameter in some regions 6 inches. More valuable for its perfume-yielding flowers. A native of both hemispheres. Wood close, heavy; much used in India for ship knees and tent pegs.

Acacia glaucescens.—Stem diameter 18 inches. Wood dark, resembling rosewood, fragrant and close-grained; used by cabinetmakers and for tool handles.

Acacia harpophylla.—Stem diameter 18 to 24 inches. Wood brown, hard, heavy, elastic, straight-grained; has the fragrance of violets; much used for turnery; lasts many years in the ground.

Acacia homalophylla.—Stem diameter 1 foot. Wood hard, durable, and heavy (specific gravity 1.124), very fragrant; used for fancy articles, cabinet work, and tobacco pipes.

Acacia implexa.—Stem diameter 12 inches. The wood resembles that of *Acacia melanoxylon*, and is used for cogwheels and wagon hubs.

Acacia longifolia and its varieties have stem diameters of 9 to 12 inches. The wood is white, yellow, and brown in color, light, tough, hard; used for handles of axes and other tools. *A. longifolia* and its varieties are the most valuable among the sand-binding species.

Acacia macradenia.—Stem diameter 12 inches. Wood strong, hard, and blackish. Takes a fine polish.

Acacia neriifolia.—Stem diameter 12 inches. Wood light yellow and dark brown; handsome, close-grained, durable; used in cabinet work.

Acacia pendula.—Stem diameter 12 inches. Wood very hard, close-grained, richly marked, dark in color, very fragrant; used for veneers and fancy cabinet work.

Acacia pycnantha.—Stem diameter 9 inches. Wood very tough, weighs about 51 pounds to the cubic foot; used for staves, bobbins, and various articles of turnery.

Acacia salicina.—Stem diameter 15 inches; wood heavy, handsome, dark brown in color; weight of cubic foot 47 pounds; takes a high polish; much used for furniture.

Acacia stenophylla.—Stem diameter 20 inches. Wood very solid, close-grained, dark; takes a superior polish. Is called "ironwood," and is much used by cabinetmakers.

Acacia sub-porosa.—Stem diameter 18 inches. Wood extremely tough and elastic; used for wagon poles, tool handles, gunstocks; also for spars of coasting vessels.

Acacia koa, of the Hawaiian Islands, has a stem diameter sometimes 2 or 3 feet and is considered the best timber tree of the islands. Its wood is easy to work, hard, handsome, in great demand for furniture, boats, and building generally. It grows at an elevation of 4,000 feet above the ocean. The few remaining forests of this acacia should be protected and young plantations established to supply future needs. The tree has not yet been sufficiently tested in California.

Acacia catechu.—An even more valuable acacia is *Acacia catechu* of India. Stem diameter 2 feet. The heart wood, which is more durable than teak, is not attacked by insects. The weight of this timber is 70 pounds per cubic foot, and it is used for pestles, crushers, rollers, and all sorts of wheelwrights' work.

Besides these 25 species there are about 20 more which have not yet been tested in the United States, but whose wood is highly valued in their native countries for beauty or durability.

Timber Acacias in California.

Few of the trees which have been cut in California for wood specimens have been more than 20 years old, nor have they had diameters greater than 18 inches. Larger trees are usually so ornamental that owners dislike to cut them. But these older and larger trees would show a better quality of timber. Another thing that should be taken into consideration is that none of the timber species have been grown in California under forest conditions. The specimens in Hough's "American Woods" were grown in Alameda County as park trees. In California, *Acacia melanoxylon*, the best of the timber acacias, has made a diameter growth of 18 inches in as many years, and trees 25 years of age attain the height of 60 feet and a diameter, in some few cases, of as much as 30 inches. It is often planted as a street tree, and its ability to thrive near gas works and manufacturing establishments, where nearly every other species of tree will perish, has already been commented upon. In Shasta and Amador Counties it has been noted that this acacia is markedly resistant to the fumes of copper smelting. In Oakland there are good specimens thriving on refuse dumps and in sewage. It will stand much surplus water, alkali, and

sea salt. It is, however, not particularly frost hardy and is a tree for low, moist situations.

It has one great advantage for forest management as a timber tree, and that is its power of reproduction over large areas from root suckers. When a tree is cut down many such suckers spring up, even at a distance of from 30 to 40 feet from the parent stem, and these eventually make sturdy trees.

Acacia farnesiana was found at some of the California missions when the Americans came from the East and while it is not a large tree it should be valuable in California not only for its timber but for its perfume. *Koa* has not been sufficiently tested as yet in California, but its record in Hawaii points to great usefulness if it can be grown in commercial plantations.

Nearly all of the hardwood required by the makers of agricultural implements, wagons, carriages, railway coaches, street cars, furniture, and cabinets, or used in the interior finish of houses and boats is imported into California and becomes year by year more costly and harder to obtain. The eucalypts, because of the difficulties of seasoning and working, are not filling the bill and the acacias may be expected to help out considerably.

OTHER ECONOMIC USES OF ACACIAS.

Forage.

The acacias as legumes have value as browse for wild and domestic animals. Those which contain a large proportion of tannin are, of course, not particularly relished by animals, but since the tannin content of the different species varies greatly, there are a number which do not have this drawback. In the great African and Asiatic deserts the leaves and young shoots of acacias form the principal browse of goats and camels. In Australia certain species are of considerable value for cattle, sheep, and other live stock. Since some of the most useful forage acacias are also valuable for the fixation of drifting sands, seacoast thickets of these shrubs have a double economic value.

The Australian "scrub," locally known as "myall" and "mulga," consists of some 30 species of acacia, many of which display great drought-resisting qualities. The four best forage species, in the opinion of Dr. Maiden, are *Acacia aneura*, *A. doratoxylon*, *A. pendula*, and *A. saligna*. To these might be added *Albizzia lophantha*, still catalogued by many California nurserymen as an acacia, which is particularly well adapted to seacoast conditions.

Australian cattlemen say that saltbush (*Atriplex semibaccata*) and myall make the best beef products on that continent. The best

myalls thrive in California, especially on the sand hills, where they endure hard conditions. They would succeed on the Carissa Plains of San Luis Obispo and on the west side of the San Joaquin Valley.

In some parts of California albizzias have become naturalized, have fixed the sand, furnish forage, and still continue to extend themselves. On the sand dunes about a mile north of Morro Rock, San Luis Obispo County, *Albizzia lophantha*, self-seeded from a few dooryard trees 45 years ago, has gradually extended over about 50 acres. Each plant was browsed down to a mere green mat, which, like Thoreau's famous wild apple tree, finally become so wide across that the enemy could not bite off the central shoot, which then took heart of grace, grew high, became a tree, and seeded a new area.

The adaptability of these forage-yielding acacias and albizzia to the deserts of Mojave and Colorado can be determined, of course, only by actual trials. But it is not unreasonable to hope that several such exotic species may hold the soil and furnish forage at the same time.

In planting care should be taken to adhere closely to the few species which have been mentioned as valuable for forage, because some of the acacias are poisonous and sheep and cattle have been killed by eating the green buds.

Shelter Belts.

In all regions of brisk winds and a high rate of evaporation shelter belts are necessary to successful agriculture. In New Zealand the larger acacias are generally preferred to eucalypts for shelter-belt planting about orchards and fields; they take less from the soil, and in consequence crops can be grown closer to them. *Acacia decurrens* in its several varieties is best suited for this purpose, the seed to be sown where it is desired that the trees shall stand.

Some of the smaller acacias form excellent hedges and barriers, requiring almost no pruning and no irrigation. There are about 40 species well adapted to hedge purposes, and their local names testify to their effectiveness—"wait a bit," "dead finish," and "kangaroo thorn." *Acacia armata* is well adapted to the coast districts, and while it is graceful and seemingly harmless it constitutes an impenetrable barrier. *Acacia furox* is a South African species which forms an especially good hedge. *Acacia arabica* forms large, strong barriers. Even the thornless and very ornamental acacias can be grown close to the ground and become protective barriers as well as attractive masses of bloom in their flowering season. The fragrant *Acacia farnesiana* is often used for hedges, and *Acacia cultriformis*, *A. cyanophylla*, and *A. baileyana* are beautiful specimens for large barriers.

Gum Products.

Several species of acacia already naturalized in America yield substances of great economic value, although in this country they are not as yet commercially utilized.

One of the most important of these substances is lac, the product of an insect (*Tacharia lacca*) of the coccid family, which feeds on the juices of many host plants and especially on certain acacias. Lac culture is a large and profitable industry in several countries and there is an increasing demand for the product. The literature of the industry is voluminous, particularly in the forest publications of the Government of India,[1] where *Acacia catechu* and *A. arabica* are cultivated as hosts for the lac insect. *Acacia farnesiana*, perhaps more valuable for perfumes, is also a lac-yielding species, as is the American *Acacia greggi* of Arizona. Since the value of the lac product on various species differs greatly, there is room for wide experimentation with those grown in America; it is generally considered, however, that *Acacia catechu*, the "kair tree" of India, is one of the best.

Gum arabic.—Any mention of vegetable gums immediately brings to mind the widely known gum arabic, derived from *Acacia arabica* as the type, but yielded also by a number of Asiatic and African desert species, all of which thrive in the warmer parts of the United States, and growing where the date palm has been successfully introduced, but requiring much less moisture. They are strongly alkali resistant and are adapted to true desert conditions. They should prove of value, therefore, in southern California, Arizona, and New Mexico. The more valuable gums used in medicine and in various arts and industries come from the *Acacia arabica*, *A. senegal*, *A. suma*, *A. verek*, *A. farnesiana*, *A. stenocarpa*, *A. gummifera*, *A. etbaica* and others. The yield is variously graded and is marked under several trade names. Single trees will flow each year from a few ounces to a few pounds of gum, and the bleeding process can be continued for many years without harm to the plant.

Many other gums are yielded by acacias, some of them highly astringent. Cutch, a product of *Acacia catechu*, is in constant demand and reaches market in several forms, as crystals found in the wood and as a gum, both pale and dark.

The cheaper grades of gum are yielded mainly by the Australian acacias and are in general use. All of the *decurrens* varieties of tanbark acacias yield commercial gums in large quantities, known specifically as wattle gums and used as a size for leather, as a substitute for isinglass, and for many other industrial purposes. *Acacia binervata*, *A. pendula*, *A. glaucescens*, *A. retinoides*, *A. homalophylla*,

[1] In this connection there is a suggestive paper on the propagation and collection of lac contributed by Mr. Lowrie, deputy forest conservator, to the Nagpur Forest Conference of 1908.

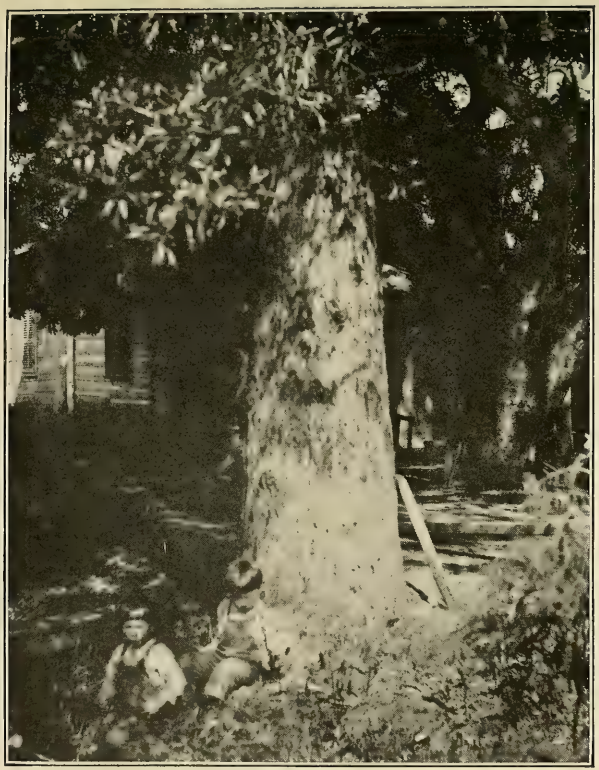


FIG. 1.—THE TRUNK OF A 30-YEAR-OLD ACACIA MELANOXYLON, 3 FEET IN DIAMETER, NILES, CAL.

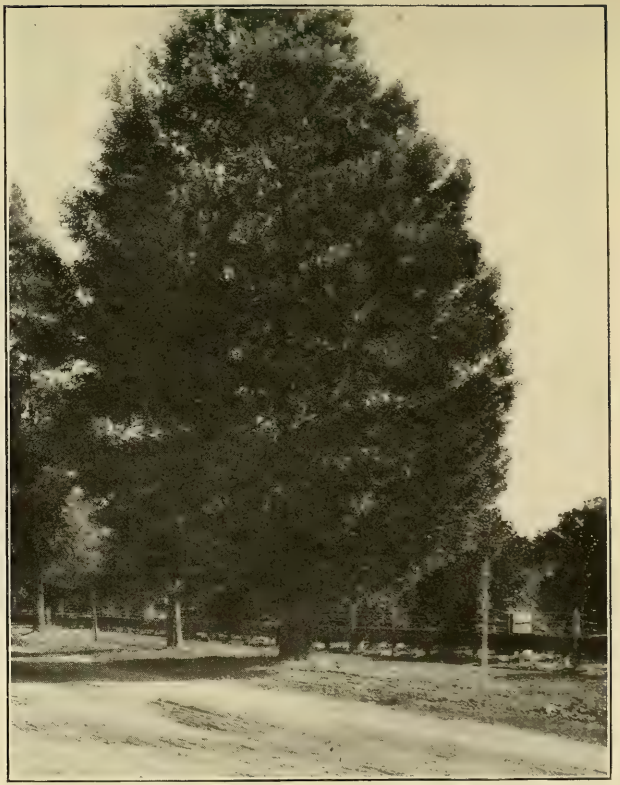


FIG. 2.—TWELVE-YEAR-OLD ACACIA MELANOXYLON, AS STREET TREES, POMONA, CAL.

FIG. 1.—CROSS SECTION OF CALIFORNIA-GROWN ACACIA MELANOXYLON, 18 YEARS OLD; ONE OF SEVERAL TRUNKS FROM THE SAME ROOT.

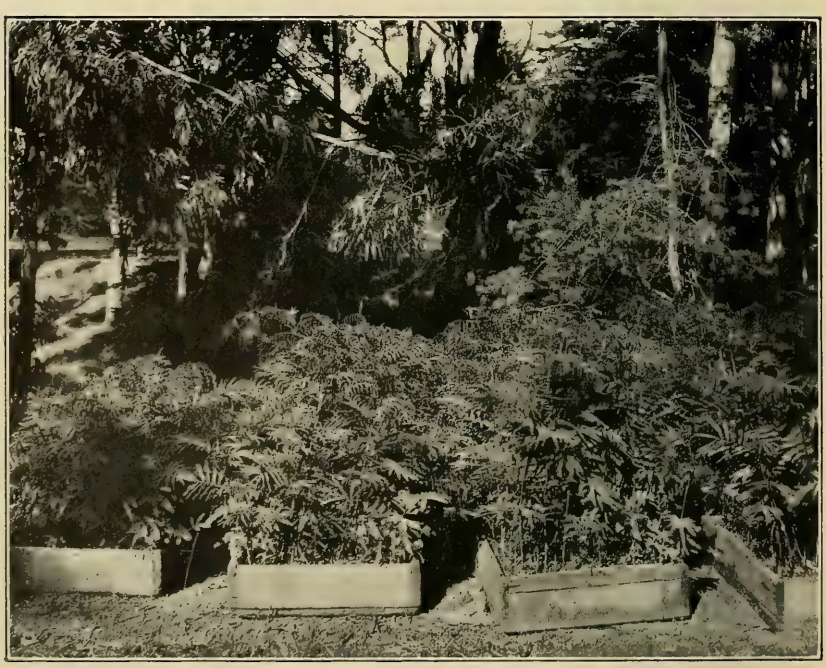


FIG. 2.—FLATS OF NURSERY-GROWN ACACIAS READY TO BE SET OUT.

A. microbotya, and in fact nearly every acacia which is grown in California yield useful gum.

The best gum invariably comes from trees grown under arid conditions, and as a rule the quantity depends upon the climate and the yield increases with drought and summer heat.

Perfumes.

One species of acacia, *Acacia farnesiana*, the "cassie" of the French, takes high economic rank. It is said to have been known to Dioscorides, a Greek medical writer of the second century. Bentham thought this species was indigenous to western America from Chile to Texas and also to northern Australia; Von Mueller says: "Indigenous to south Asia westward as far as Japan. *Acacia acnifera*, endemic on the Bahamas, is very closely related to *A. farnesiana*." It is now known, however, that *A. farnesiana* is native to the high plateaus of central Africa. Mr. J. M. Purvis, chief forest officer, Nyassa Land Protectorate, writing recently from Zomba, has reported to the author that *A. farnesiana* is very common there.

Mr. H. Nehrling describes specimens in Florida 16 feet high and only 8 years old. Mr. H. Plant reports a 30-foot tree in northern Mexico. In California the largest are now from 20 to 25 feet high. Dense thickets of this acacia grow near the ruins of San Diego Mission and about other Spanish settlements. As a shrub it is not as handsome as many others, but it is perfectly adapted to large areas in America, because it is considerably hardier than the Australian species and thrives better in regions of summer rains.

The acacia-perfume industry, as carried on principally at Grasse, France, is very attractive and profitable. A full-grown tree yields about 300 pounds of flowers. The industry has been so often described that all the details of the extraction of the perfume are readily accessible. All that needs to be noted here is that a number of Australian acacias, such as *A. pycnantha* and *A. suavolens*, are used for the production of perfumes as well as *A. farnesiana*. The industry utilizes poor soils incapable of bearing grain or fruit crops, and gives light and pleasant outdoor employment to women and children.

Dyes, Medicines, Foods, and Fibers.

Several species of Australian and South American acacias furnish yellow, brown, and red dyes which are both cheap and easily obtained.

Bentham, Von Mueller, Maiden, and others have investigated the medicinal properties of acacias, but the subject, like that of acacia dyes, requires more work from specialists. It is generally known that all of the wattle acacias and many of the Asiatic and South American species are serviceably astringent. The pods and the galls

which grow on some species are locally esteemed as medicines. Salicin and saponin are yielded abundantly by several of the Australian species. The food and fiber uses of the acacias, while interesting, are commercially unimportant, and are mainly confined to the Australian species. Thozet says that the roots of *Acacia bidwillii* are edible after baking. Wattle seeds require much boiling or roasting to make them palatable, and the seeds of many species give off a most disagreeable odor when cooked. No acacia is cultivated primarily as a food plant.

PROPAGATION AND MANAGEMENT OF ACACIAS.

The conditions which govern successful acacia growing are not complex and should be readily understood by any intelligent planter. Nevertheless, there have been many failures in the propagation of acacias and large unnecessary expense. There can be no profit in growing trees of any sort for tanbark, timber, or fuel unless the expense is far below that of a nurseryman's ordinary outlay, which of course includes the cost of many transplantings and much handling of the stock. If healthy trees, well established, can not be obtained at less than half a cent a piece, the forest management of acacias will not be profitable. As a matter of fact, however, trees can be obtained at this low price.

PLANTING.

Direct Seeding.

The simple and natural way to secure an acacia plantation is to sow the seed where it is desired that the trees shall stand. This is the method followed, with local modifications, in South Africa, Algeria, India, and Australia. The method has never been adopted in California, however, except experimentally on a small scale, yet there is little reason to doubt that it will be successful in connection with a careful study of local conditions. In no other way can large plantations be cheaply established.

The seeds of acacias resemble those of common locust (*Robinia pseudacacia*), though generally smaller, and like them have a thick, hard, protective shell. Their germinative power and ability to grow rapidly is very great, and few classes of tree seeds are so well adapted to make a start and to maintain life under difficult conditions. In nearly all cases the seed has to be prepared for rapid germination. The Australian authorities say that it will sometimes remain dormant in the ground for years. Dr. Hilgard has noted an instance at Berkeley, Cal., where young acacias came up 14 years after the parent tree had been removed. Since no other tree of the same species was anywhere in the neighborhood, it is probable that the seed had lain all that time without germinating. Especially in light soils and

in seasons of scanty rainfall it seems wise, therefore, to assist the germinating process. Usually this is done by placing seed in a vessel and pouring over it boiling water, leaving the seed to soak and swell for from 24 to 48 hours. Seed may even be boiled for some minutes without injury.

Seed may be prepared for germination by dry as well as by moist heat; in other words, it may be more or less roasted. After every fire in the Australian "bush" perfect forests of young wattles spring up. Some planters burn brushwood to embers and then mix the acacia seed with ashes and dying coals, leaving it for several days. Sometimes, too, seed may be shaken in a frying pan over the fire.

In California it has been observed that acacia seedlings come up abundantly where piles of acacia brush have been burned, usually in rings several inches wide around each brush pile. Where the short, dry grass and weeds under acacia groves have been burned reproduction has been assisted both in quantity and distribution.

The following tests, reported by Mr. J. E. Brown (Australia) show the effects of various treatments of the seed:

Acacia pycnantha.—Five parcels of seed saturated with water at temperatures of 150° F., 170°, 190°, 200°, and 212°, respectively. All germinated well in three weeks. Four parcels of seed boiled for 1, 3, 5, and 7 minutes, respectively. All germinated in 18 days.

Acacia saligna.—Seed saturated in boiling water germinated in one week.

Acacia decurrens.—Seed saturated with boiling water and then swelled in wet sand. Germinated in two weeks.

Tests made for this report on California grown seed are as follows:

Acacia pycnantha.—Seed boiled for 5 minutes germinated 30 per cent in 4 days, with nearly all of the remaining seed still sound at the end of 11 days.

Acacia melanoxylon.—Seed boiled 2 minutes germinated 20 per cent at the end of 11 days. Boiled 7 minutes germinated 6 per cent. Much of the seed, however, was sound and simply required more time to sprout.

Acacia cyanophylla.—Seed boiled 2 minutes germinated 70 per cent; boiled 5 minutes germinated 64 per cent; boiled 10 minutes germinated 4 per cent.

After the seed has been heated it may be mixed with damp sand and left until sprouting before it is sown. The objections to this process are that it can not then be drilled and the seedling is more likely to succumb in case of protracted dry weather. Mr. Perrin, state conservator of forests, Victoria, mixes half a bushel of sand with each pound of seed and broadcasts. Some planters sow the seed on top of plowed ground; others cover with a harrow. Where there is a loose soil sheep may be driven over the tract to tread in the seed. Often barley is sown with the acacia seed to serve as a shelter. It is said that some successful plantations have been started in the scrub in Australia. Possibly there are places in California where the chaparral could be broadcasted with profit, but as a rule clearing is necessary. It is claimed that the seed of tanbark acacias is hardly

ever subject to depredations by rodents, and that gophers will not gnaw their roots.

After a plantation is established the natural way to secure reproduction is to depend upon self-sown seedlings. It is likely, however, that these may come up irregularly, and that the use of the drill or transplants may be necessary to secure a uniform stand. The mere fact that acacias become naturalized and spread over waste places in parts of India, Africa, Algeria, California, and the Southwest does not necessarily imply that well-stocked groves can be produced invariably without aiding nature.

The method of planting known in the Forest Service as seed spotting, equivalent to planting in hills, has several advantages over broadcasting. It saves a great deal of seed; it enables the planter to pick out the best spots and to prepare them with some care; and it greatly reduces the cost of subsequent thinnings. In many cases land may be so well prepared that seed could be drilled in or sown by hand in rows. Thorough cultivation of the ground is of course desirable, yet excellent plantations have been established with less cost of time and labor. For example, at Mount Benson, South Australia, where the soil is very poor—the mere white sand of the "fern hills"—double furrows 8 feet apart were struck out. Seed which had been soaked in boiling water was drilled in and covered with a harrow, 1 pound to the acre. In some places it would be practicable to attach drill and harrow to the plow and complete the whole planting operation at one time. One man and a team can plant 8 acres a day.

Use of Nursery Stock.

Nursery methods are too expensive for the forester except to supplement field sowing. They involve skilled labor and the use of considerable material such as seed boxes and flats and pots, either of paper or clay. In India sections of bamboo are used for the plants, which are set in the ground as soon as the seedling is ready for the field. In Australia stems of the reed *Arundo donax* have been used at a cost of $1.25 a thousand tubes, this price including the cutting of the reeds, filling the sections with earth, and setting out the plants.

California nurserymen sow their acacia seed beds in June, July, and August, and the plants are ready to be transplanted to pots or to be set out the following spring. The seed-bed method entails a heavy loss, and boxes, flats, or trays are usually preferable and cheaper. These flats are generally 4 inches deep and contain 2 or 3 square feet. Each one will hold from 100 to 200 plants of transplant size. Generally they are sheltered from sun and wind by lath houses, by brush, or by being placed under large trees. One laborer can care for many thousand of these small acacias in the flats, which

need only to be watered every evening and to be thinned so that the plants will stand an inch or so apart.

SPROUTING AND LAYERING.

All the tanbark wattles sprout readily from the stump, and this method of crop reproduction is especially valuable when acacias are grown for firewood. The sand-reclaiming acacias will root even from the recumbent stems. This helps them to spread over the ground. This natural layering process can be aided by slashing the lower branches, bending them down, and covering the gash with earth. *A. saligna* and *A. longifolia* thus treated spread almost as well as willows.

GENERAL CONCLUSIONS.

The most important fact derived from an economic study of acacias in California is that after some fifty years many species of acacia have proven themselves to be entirely at home over large areas, and have in fact become naturalized. They are worth the careful investigation of tree planters and foresters, for they fill a place which is not occupied by any other group of exotic trees. Since many of them make only slight requirements on moisture and soil, their cultivation need not interfere with that of other exotic trees for special products, such as the Japanese chestnut, cork oak, camphor tree, date palm, eucalypts, algaroba or carob, and maritime pine.

The unique field occupied by acacia tanbark and by some other products, especially the gums, and the usefulness of the best acacia woods would seem to justify the general conclusion that plantations properly located and managed are as likely to prosper in America as in other countries. But before extensive commercial operations are decided upon there is need for more complete and painstaking work upon the acacias—their growth and their products—the study to be based upon American-grown trees. As yet the rates of growth and the yields of various species on different soils, especially under plantation conditions, are not definitely determined. Unless such preliminary scientific investigation is undertaken and its evidence accepted, it is likely that industries based upon acacias may be exploited too hastily, and, therefore, present failures will give setbacks such as have resulted where the culture of any particular tree has become a fad. These failures are likely to do much to deter properly qualified persons from entering upon an industry which should ultimately become established on solid foundations.

So far, acacias have been planted in the United States simply as ornamentals, and the information secured from a study of these specimens has been chiefly cultural. They have proved that the

best acacias thrive in California, and that they will grow on poor and arid soils, where there is little or no frost. Beyond this there is not much information, and some misinformation. For example, they are commonly bracketed with the eucalypts in the minds of many persons, simply because the eucalypts and most of the acacias come from Australia. The place occupied by the acacias, however, is as distinct from that of the eucalypts as both are from oaks or from conifers.

To successfully develop commercial plantations of acacias in the United States, at least three problems will need to be solved. First, the behavior of the trees under close-planted commercial conditions must be known, and this can be learned only from experimental plantations. Second, the various labor-saving economies will have to be studied, and methods standardized, because American economic conditions are markedly different from those of Natal, Hawaii, the Transvaal, and Australia. Third, and probably most important and difficult, will be the problem of marketing the products in competition with those produced cheaply abroad.

It will probably be very easy for American planters to duplicate the working plans of acacia growers elsewhere, or even to improve upon them as far as American conditions will induce changes in details. Successful acacia culture depends primarily upon good farm practice. Hard-working, practical men, even without special training in forestry, have created great plantations. It is likely that the same thing will occur in this country. At the same time the true spirit of scientific investigation, the power of observing and drawing correct conclusions are essential to the development of this industry along new lines.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 10

Contribution from Office of Experiment Stations, A. C. True, Director.
October 30, 1913.

PROGRESS REPORT OF COOPERATIVE IRRIGATION EXPERIMENTS AT CALIFORNIA UNIVERSITY FARM, DAVIS, CAL., 1909–1912.

By S. H. Beckett,
Irrigation Engineer.

INTRODUCTION.

The experiments herein described were planned and carried out for the purpose of determining the water requirements of various standard crops. For the purpose a tract of 25 acres on the University farm at Davis was set aside by the college of agriculture. The work was planned and carried on by the irrigation investigations of the Office of Experiment Stations, in cooperation with the department of engineering of the State of California, the California Experiment Station furnishing seed and a part of the labor in return for the crops.

The University farm, comprising 779 acres, lies one-half mile west of the town of Davis. The soil, which is typical of that of a great portion of the Sacramento Valley, is classed as Yolo loam, described by the Bureau of Soils of this department, as follows:

> The surface soil of the Yolo loam consists of a dark-brown loam of light to rather heavy texture. The soil is usually free from gravel. Below a depth of 24 inches the subsoil is generally made up of strata of silty loam or sandy loam. At greater depths this rests on clay loam or clay. * * *
>
> Owing to the excellent drainage and comparatively open texture of this type it has proved to be well adapted to fruit, including peaches, almonds, prunes, and grapes. * * * While irrigation has not been in general use, it has been found to be beneficial to the tree and fruit where the lower strata of the soil lack the close texture and compactness necessary for the retention of moisture. It is one of the best general-purpose soils in the region and is adapted to a wide range of crops.[1]

The mean annual rainfall, although slightly below the average for the Sacramento Valley as a whole, amounts to 16.54 inches, the greater part of which comes in December, January, February, and March, while from May to October very little rain falls. A mean temperature of 77.9° F. is recorded for the month of July, the mean

[1] U. S. Dept. Agr., Bur. Soils, Field Operations 1909, Eleventh Report, pp. 1657, 1658.

minimum of 47.6° F. occurring in January. The maximum temperature recorded is 112° F., and 16° F. has been registered as a minimum. These extremes are exceptional, however.

As a preliminary step in starting the experiments at Davis, a 12-inch well was sunk near the northeast corner of the tract and a 4-inch horizontal centrifugal pump, directly connected with a 7½-horsepower motor was installed, thus insuring a reliable water supply. Water was delivered to the various checks and field laterals through 8-inch galvanized-iron slip-joint pipe. When properly fitted together this was practically watertight, eliminating loss in transportation.

Before starting each irrigation the discharge from the pump was measured over an 18-inch Cippoletti weir, and the measurements were used in computing the amount of water applied.

IRRIGATION OF ALFALFA.

Operations were started in 1907, and in the fall of that year the major portion of the tract was leveled for alfalfa irrigation. Border, rectangular, and contour systems of checks were used, and at the time it was intended to rely upon the open-ditch system of the Yolo County Consolidated Water Co. for water. The accompanying sketch (fig. 1) shows the system of checks and ditches installed, the acreage of each check, and its number, which will be used in future designation.

During the whole of 1908 the land stood idle. Early in March, 1909, plats 1 to 28, 32, 33, 34, and the west half of 35, 36, and 37 were thoroughly disked, cross-disked, harrowed, and seeded to alfalfa, 20 pounds of Utah seed per acre being used. A grain drill, with alfalfa attachments, was used which placed the seed at a depth of about 1 to 1½ inches in the soil, in rows 6 inches apart. A good uniform stand was obtained, and by the middle of May a 3-inch to 4-inch growth had been made.

The following schedule for the season's irrigation was outlined and closely followed:

Schedule of irrigation, 1909.

Number of plat.	Number of irrigations.	Dates of irrigation.	Depth of water applied.
			Inches.
1 to 4	No irrigation		
5 to 9	1 early	June 5	15.0
32, 33	1 midseason	July 14	6.1
10 to 15	1 late	August 10	14.3
36	1 very late	September 9	10.6
20 to 23	1 early, 1 late	May 31	12.5
		August 10	15.4
24 to 28	2 late	July 14	7.8
		August 23	7.0
37	2 very late	August 1	9.4
		September 9	8.9
16 to 19	3 early	May 29	12.5
	3 midseason	July 13	7.2
	3 late	August 23	7.0

During the growing season the growth and condition of the crops were carefully observed, and at the end of the season the results were as stated below:

No irrigation.—At the end of November only about one-third of the stand seemed to be alive, and this had made not more than a 1 or 2 inch growth after it was first cut in June.

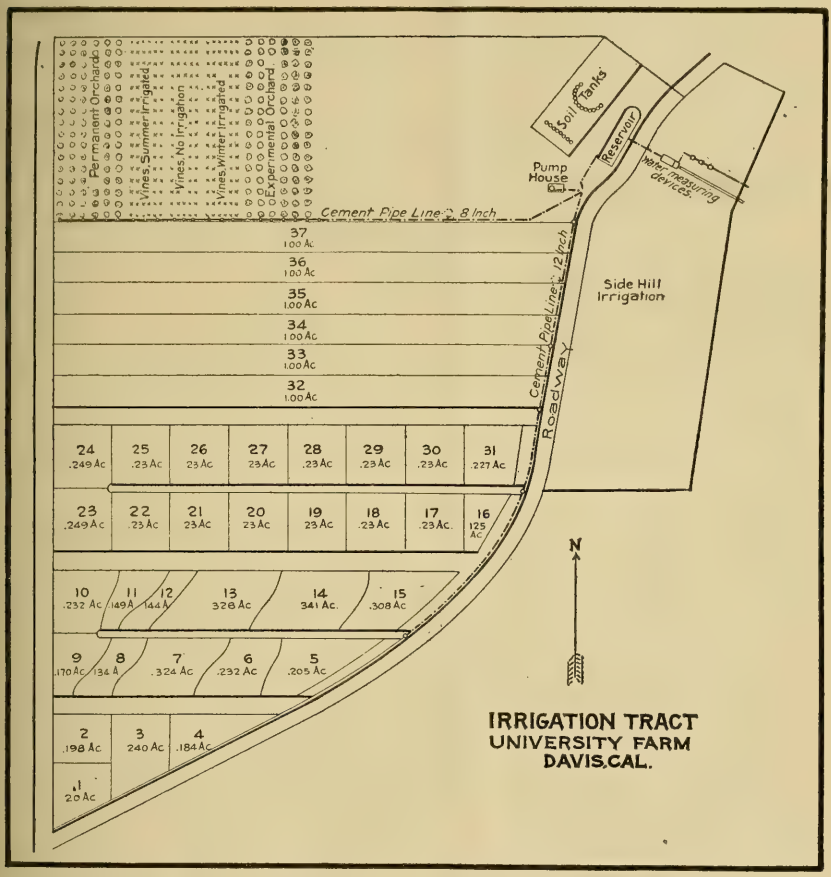

FIG. 1.—Irrigation tract, University farm, Davis, Cal.

One irrigation.—The alfalfa given one early irrigation showed practically no growth after the first cutting on May 14. Even after the heavy irrigation of June 5 it failed to make a substantial growth, and at the end of the season not more than one-half of it was alive. The explanation of this is that it was given too early an irrigation. The plats were irrigated before the roots had penetrated beyond the surface soil, and when this had dried out, following the first irrigation, the roots were stranded in a surface soil without sufficient moisture to forward the growth.

The midsummer irrigation of July 14 produced two very light crops and left the plants alive but growing very slowly at the end of the season. Before this first irrigation was applied the root system had time to penetrate well into the subsoil and receive full benefit from the irrigation after it was applied.

The late and very late irrigations both produced one fair crop besides the first light crop cut in May, and at the end of the season all of the alfalfa had shown a vigorous growth, with no apparent effects from the early drought, indications pointing toward a good yield in the spring.

Two irrigations.—In the plats given one early and one late irrigation only a 2-inch growth was shown between the cutting in the middle of June and the irrigation on August 10. Following the first irrigation the alfalfa made a slight growth, but it was not until after the second application that a substantial growth was made, which produced one fair cutting in September.

One midsummer and one late irrigation produced a fair cutting in September, followed by a second and much heavier crop early in November. At the time of this last cutting the stand was in very good condition, the plants being deep-rooted and sturdy.

Two late irrigations of 9.4 and 8.9 inches, respectively, applied August 1 and September 9, produced two good crops, the first on September 7 and the last November 12, and at the end of the season these plats had not only produced the heaviest first-season yields, but contained the hardiest and best appearing plants.

Three irrigations.—In these plats the first and heaviest irrigation, applied May 29, seemed to have little effect upon the stand aside from keeping it alive; but after the second application, on July 13, the growth was rapid; and following the third application of August 23 a heavy first-year crop was taken off October 12, and a second fair crop in November, and at the end of the season the plants seemed to be very well developed, indicating probable heavy yields the following spring.

Late in November plats 35, 36, and 37 were all given a very heavy early-winter irrigation. This was waste water pumped onto the plats during the testing out of the pumping plant, and, all told, the water applied must have amounted to a depth of about 18 inches. This seemed to have a remarkable effect upon the stand and was directly responsible for a heavy yield with small amounts of water the following summer.

Although no definite conclusions can be drawn from a single season's observations, nevertheless the results obtained point to the following facts:

(1) Without irrigation spring-sown alfalfa is uncertain in Sacramento Valley, and under conditions of normal rainfall and moderate

climate not more than one-half of the stand can be expected to survive through the summer.

(2) Heavy spring irrigations, when followed by long periods throughout the summer without water, did not benefit alfalfa. Examination of the root growth under these conditions shows that water applied to the little plants in the early spring produces a root growth outwardly along the surface of the soil rather than downward, and when this is followed by long dry periods, the soil drying out leaves the young plant stranded above the moisture zone. Far better results were obtained by delaying irrigation until the root growth was well established, and even until the little plants seemed to be stunted and suffering for moisture. Well-developed, deep-rooted plants mean heavier yields.

(3) Late and very late summer irrigations tend to produce sturdier plants and heavier yields the following summer.

(4) After the root growth is well established, the growth may then be forced by frequent and, if the soil will stand it, heavy irrigations.

DUTY OF WATER FOR ALFALFA, 1910, 1911, AND 1912.

The investigations during the first year's growth of the alfalfa had naturally destroyed the uniformity of the stand, making it necessary to reseed the whole area. Early in March the ground was thoroughly disked, cross-disked, and harrowed to a depth of 2 inches. It was then reseeded, 20 pounds of Utah seed per acre being drilled in at right angles to the seeding of the year before. This seed was brought up by the early spring rains and at the time of the first cutting on April 21 a very uniform stand covered the whole area.

The previous year's work had shown that the water supply from the ditch system was inadequate for experimental work, and the pumping plant was installed and used in all subsequent work, the ditch system being abandoned.

The following schedule for irrigation was outlined and followed on all but three of the checks in 1910 and 1911:

Schedule of irrigation of alfalfa, 1910 and 1911.

Number of plat.	Area.	Depth of water applied.	Schedule.
	Acres.	*Inches.*	
1, 2, 3, 4	0.822	.....	No irrigation.
9, 10, 11	.536	.....	Do.
8, 12	.293	12	6 inches after first and second cuttings.
7, 13	.652	24	8 after first, second, and third cuttings.
22, 23, 24, 25	.960	30	7½ after first, second, third, and fourth cuttings.
17, 18, 19, 28	.920	30	3¾ inches one week after first, second, third, and fourth cuttings; 3¾ inches before second, third, fourth, and fifth cuttings.
20, 21, 26, 27	.920	30	7½ inches one week before second, third, fourth, and fifth cuttings.
33	1.000	36	12 inches after first; 8 inches after second, third, and fourth cuttings.
6, 14	.573	36	9 inches after first, second, third, and fourth cuttings.
32	1.000	48	12 inches after first, second, third, and fourth cuttings.
5, 15	.513	48	Do.

A winter irrigation applied to checks 35, 36, and 37 produced a marked improvement in the stand which was carried over into the following season, producing much heavier yields. For this reason they were treated separately, the following schedule being used:

Schedule of irrigation of alfalfa, 1910 and 1911.

Number of plat.	Area.	Season of 1910.	Season of 1911.
	Acres.		
35	0.50	24 inches applied, 12 inches after first; 6 inches after second and third cuttings.	24 inches applied; 12 inches after first; 6 inches after second and third cuttings.
36	.50	30 inches applied; 12 inches after first; 6 inches after second, third, and fourth cuttings.	24 inches applied; 8 inches after second, third, and fourth cuttings.
37	.50	30 inches applied; 12 inches after first; 6 inches after second, third, and fourth cuttings.	24 inches applied; 6 inches after first, second, third, and fourth cuttings.

This work was continued during the season of 1912 but on a reduced area, rectangular checks 17 to 31 being devoted to the work. Application of equal amounts of water to these checks during 1910 and 1911 had produced a very uniform stand over the whole area, and the experiments were started in 1912 under very favorable conditions. Following is the schedule outlined and followed during the season:

Schedule of irrigation of alfalfa, 1912.

Number of plat.	Area.	Depth of water applied.	Schedule.
	Acres.	*Inches.*	
17, 30	0.46	.....	No irrigation.
18, 29	.46	12	6 inches after first and second cuttings.
19, 28	.46	18	6 inches after first, second, and third cuttings.
20–27	.46	24	6 inches after first, second, third, and fourth cuttings.
21–26	.46	30	7½ inches after first, second, third, and fourth cuttings.
22–25	.46	36	9 inches after first, second, third, and fourth cuttings.
23–24	.50	48	12 inches after first, second, third, and fourth cuttings.
31	.23	60	12 inches after first, second, third, fourth, and fifth cuttings.

During each of the three seasons six crops of hay were cut. In harvesting, the general practice of cutting when about one-third of the alfalfa is in bloom was followed. The hay was generally raked the same day, shocked the day following, and hauled as soon as it was dry enough to be stacked without heating, never waiting until the leaves were dry enough to fall off when handled. The results of these experiments are given in the table following.

Summary of results of alfalfa irrigation investigations, 1910, 1911, and 1912.

Depth of water applied.	Yield in tons per acre.			Value of hay per acre at $7 per ton.			Cost of production.			Net profit per acre.		
	1910	1911	1912	1910	1911	1912	1910	1911	1912	1910	1911	1912
Inches.												
0	3.85	6.02	6.52	$26.95	$42.14	$38.64	$8.65	$13.50	$12.40	$18.30	$28.64	$26.24
12	4.75	7.52	6.51	33.25	52.64	45.57	13.40	19.60	17.35	19.85	33.04	28.22
18	.....	.....	7.02	.....	.....	49.14	.....	.....	19.85	.....	.....	29.29
24	6.00	8.38	8.32	42.00	58.66	58.24	18.90	24.20	24.10	23.10	34.46	34.14
30	7.53	9.61	9.43	52.71	67.27	66.31	23.15	27.85	27.35	29.56	39.42	38.96
36	7.58	9.33	9.38	53.00	65.31	65.66	24.15	28.05	28.10	28.91	37.26	37.56
48	8.45	9.64	8.87	59.15	67.48	62.09	27.80	30.25	28.80	31.35	37.23	33.29
60	.....	.....	10.04	.....	.....	70.20	.....	.....	33.65	.....	.....	36.63

NOTE.—Labor of production figured at $2.25 per ton. Water figured at $1.70 per acre-foot. Labor for irrigation figured at 50 cents per acre per irrigation. While the value of the hay is figured at $7 per ton for each of the three years 1910, 1911, and 1912, the local value in 1912 was $11 per ton.

The accompanying diagram (fig. 2) shows the average yields in tons per acre for the three years, with the corresponding depths of water applied, and figure 3 shows the average yield in tons per acre for each cutting from the unirrigated alfalfa and from the checks given 30 inches in four 7½-inch applications.

The first diagram shows a very uniform increase in yield up to 30 inches of water applied, above which the increase is very small, and in the case of 36 inches applied a slight decrease is shown, although the maximum average yield was produced by a total of 48 inches applied in four 12-inch irrigations.

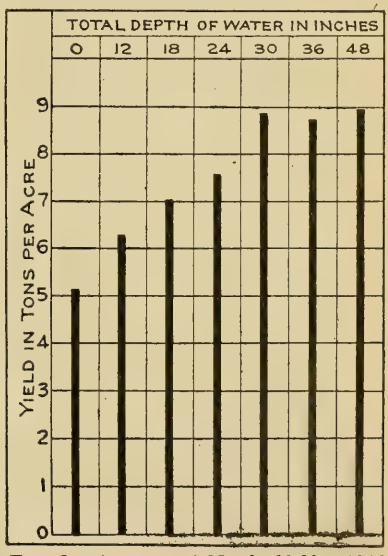

FIG. 2.—Average yield of alfalfa, 1910, 1911, and 1912, using different quantities of water.

The first half of the diagram shown in figure 3 illustrates the gradual decrease in yield in each succeeding crop where no water is applied, showing the need of irrigation after the first crop has been removed. When this first half is compared with the other half of the diagram the result of irrigation is apparent. In each of the three seasons the maximum yield was produced in the third crop, probably because of more favorable growing conditions during June and the first part of July in which this crop was grown.

The results, although not absolutely conclusive, point to the following facts:

(1) In the open, well-drained soil, typical of that found in the floor of the Sacramento Valley, the general tendency is toward an increase in yield of alfalfa with the increased amounts of water applied up to at least 48 inches.

(2) There is a limit beyond which the increase in yield will not pay for increased cost of applying the water, and for such conditions as are found on the University farm this limit is in the neighborhood of 30 inches applied as a total for the season.

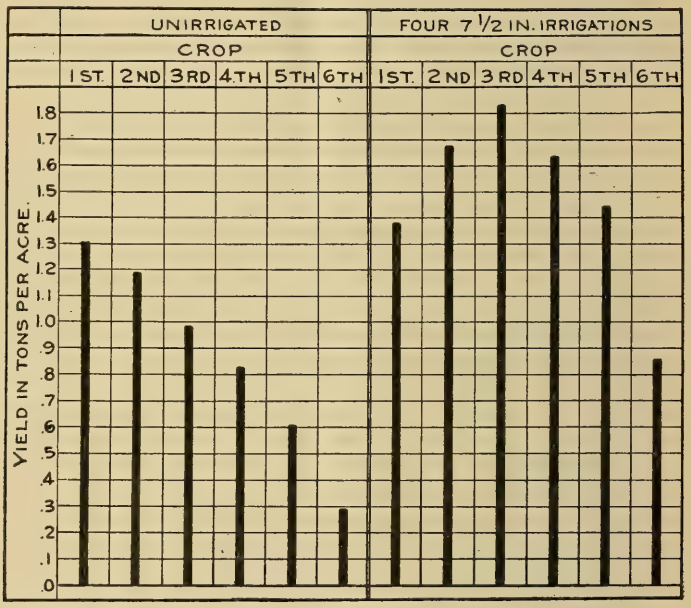

FIG. 3.—Comparative yield of unirrigated and irrigated alfalfa, by crops.

In applying these conclusions to other localities, it is well to remember that local conditions are always the controlling factors. The character and condition of the soil, the climate, the rainfall, the length of the growing season, and the age of the alfalfa, all have their effect upon the yield, and each general locality will show different results and a different economic duty of water.

WHEN TO IRRIGATE ALFALFA.

In order to determine if possible at what stage of growth after cutting the water should be applied to produce the best results, checks 17 to 28, inclusive, were divided into three groups of four checks each, and during 1910 and 1911 they were treated in the following manner:

Group 1 (checks 22, 23, 24, and 25) received a total of 30 inches, applied in four 7½-inch irrigations, immediately following the first, second, third, and fourth cuttings.

Group 2 (checks 20, 21, 26, and 27) received a total of 30 inches in eight 3¾-inch irrigations, two irrigations being applied between cuttings, the first one week after cutting and the second two weeks later.

Group 3 (checks 18, 19, 28, and 29) received a total of 30 inches in four irrigations of 7½ inches each, applied just after cutting the second, third, fourth, and fifth crops.

The results obtained are shown in the following table:

Results from irrigating alfalfa at different stages of growth.

Number of group.	Schedule.	Total yield for season in tons per acre.		
		1910	1911	Average
1	Four 7½-inch irrigations applied immediately after cutting	7.53	9.61	8.57
2	Eight 3¾-inch irrigations applied in two irrigations between cuttings	8.24	9.91	9.08
3	Four 7½-inch irrigations applied just before cutting	7.97	8.95	8.46

Each of these seasons shows a small increase in yield to be produced by two irrigations between cuttings. This averages 0.5 ton per acre for the two seasons, and if the extra labor, such as laying the pipe and preparing for the irrigation, is considered, the small additional profit is consumed in labor, and from a financial standpoint no advantage is gained.

In heavy soils, subject to cracking after irrigation, frequent application of small amounts of water shows a decided advantage over the single irrigation between cuttings. It is true also, in light porous soils where the underground drainage is good and the moisture-holding capacity of the soil is small, that one heavy irrigation will not carry the crop through to a good yield and that a second application will produce good returns.

The groups 3 and 1, irrigated before and after cutting, show opposite results for the two seasons, irrigation before cutting showing the heaviest yield in 1910 and the lightest yield in 1911, but in each case the difference is so small that no conclusions can be drawn favoring either method. It was noticed, however, that toward the end of the season of 1911 the checks irrigated just before cutting had a very spotted appearance, the alfalfa standing at a very uneven height, and that after cutting, in spots the alfalfa was slow to start its new growth. A period of five days to a week always elapsed from the time of irrigation until the crop was cut. During this time the growing alfalfa was drawing heavily upon the moisture supply in

the soil and in spots seemed to diminish it to such an extent that not enough remained to produce a vigorous growth in the plants after cutting.

IRRIGATION OF GRAIN, 1910, 1911, AND 1912.

During these three seasons the east halves of checks 35, 36, and 37, containing one-half acre each and 1½ acres of unleveled land lying north of check 37, were given over to experiments with irrigation of barley.

During 1909 checks 35, 36, and 37 were planted to sugar beets, which were irrigated, but the amounts of water added were small, and it is safe to assume had no effect upon the crops which followed in 1910. The unleveled area north of check 37 had been cropped to grain for a number of years previous to beginning the experiments, and was typical of much of the so-called "worn-out" land in the vicinity of the farm.

Season of 1910.—During the season of 1910 all plats were plowed in the early spring, harrowed, and drilled to barley on March 12, 85 pounds of seed per acre being used. The following irrigation schedule was planned and carried out.

Schedule of irrigation of barley, 1910.

Number of plat.	Number of irrigations.	Dates.	Depth applied.
			Inches.
Unleveled area	No irrigation		
35	One irrigation (flooded)	April 27	3.6
36	Two irrigations (shallow furrows)	do	3.6
		May 17	2.6
37	Two irrigations (deep furrows)		

Plats 36 and 37 were furrowed immediately after seeding. The shallow furrows of plat 36 were made by a marker consisting of two 6 by 6 inch timbers, 2½ feet long, set on edge, 18 inches apart, and fastened parallel to each other by 2 by 4 inch cross strips. This was drawn over the surface parallel with the checks, making shallow furrows 18 inches apart and averaging 1½ inches deep. This method is practically the same as flooding, the furrows acting simply as guides for the water.

It was intended to irrigate plat 37 by subirrigation from deep furrows, but the method was not successful, and May 1 the check was plowed and seeded to cowpeas, which were turned under as green manure in the fall.

The dates of irrigating plats 35 and 36 depended entirely upon the condition of the crop, the water being added when it was thought it would produce the best results and in quantities sufficient to give the soil a good irrigation.

Season of 1911.—The experiment was repeated in 1911 on the same soil, following as nearly as possible the procedure of 1910, the land being spring plowed and seeded on March 20.

The following schedule was followed during the season:

Schedule of irrigation, 1911.

Number of plat.	Number of irrigations.	Date.	Depth applied.
			Inches.
Unleveled area—north half	None		
Unleveled area—south half	One	June 1	6.4
36	do	May 13	4.3
37 [1]	do	do	6.0
35	Two	do	4.3
		May 27	2.7

[1] Green manured.

Following the seeding the weather remained cold, and at the time of the first irrigation, on May 13, 54 days after seeding, the grain stood at an average height of only 6 inches. The second irrigation was applied to plat 35 just as it was coming into the head.

On June 1 the unleveled area was divided into two plats, and the south plat flooded to a depth of 6.4 inches. At this time the grain had just come into the head and was beginning to show indications of a lack of moisture. In irrigating the remaining plats (35, 36, and 37) the water was applied at a time when it was thought it would produce the best results.

Season of 1912.—Following the harvesting of the grain in 1911, checks 35, 36, and 37 were irrigated and plowed, and on July 22 planted to cowpeas of the Clay variety. Early in November these were turned under as green manure.

February 3, 1912, these checks, as well as the unleveled area to the north, were plowed, harrowed, and seeded, using the same variety of seed, quantity, and method of seeding as in the previous two years.

Schedule of irrigation, 1912.

Number of plat.	Number of irrigations.	Date.	Depth applied.
			Inches.
Unleveled area	None		
35 [1]	do		
36 [1]	One	Apr. 24	7.35
37 [1]	Two	Apr. 17	12.00
		May 8	5.95

[1] Green manured.

It will be noticed that much heavier irrigations were applied here than in the other two seasons. In all cases sufficient water was added to give the soil a thorough wetting. The green manure seemed to produce a loose, porous soil which rapidly took up the water as it was applied. This condition will be noticed also in plat 37 of 1911, when 6.03 inches were added, as against 4.3 inches to the unmanured checks.

The following table shows the results obtained from the three seasons' work, and these are further illustrated in the diagram (fig. 4) in which the yields of grain in pounds per acre are platted, with the corresponding amounts of water applied.

Summary of results of barley irrigation, 1910, 1911, and 1912.

Season.	Rainfall for season.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.		Value.	Cost of irrigation.
					Hay.	Grain.		
	Inches.			*Inches.*	*Pounds.*	*Pounds.*		
1910	11.90	Unleveled area	None		3,120	1,160	$17.40	
		35	One	3.6	3,440	1,480	22.20	$1.08
		36	Two	5.2	4,460	1,840	27.30	1.56
1911	23.18	Unleveled area (north half).	None		1,560	805	12.08	
		36	One early	4.3	2,040	1,108	16.62	1.29
		Unleveled area (south half).	One late	6.4	2,720	1,520	22.80	1.92
		35	Two	7.0	3,180	1,810	27.15	2.10
		37[1]	One early	6.0	3,740	2,146	32.19	1.80
1912	9.46	Unleveled area	None		680	345	5.18	
		35[1]	do		1,925	1,040	15.60	
		36[1]	One	7.35	2,480	1,280	19.20	2.20
		37[1]	Two	17.95	3,780	1,950	29.25	5.38

[1] Green manured.

NOTE.—Irrigation cost figured at 30 cents per acre-inch for marking furrows, power, and attendance. Grain values figured at $1.50 per hundred. Value of hay is disregarded.

Weather records taken over the entire period of the experiment show that these three years represented extremes in rainfall and general weather conditions. Nevertheless, under all of these varying conditions there is not one instance where the increase in yield did not more than pay for the cost of the water which produced it, the yield increasing with the increased amounts of water applied.

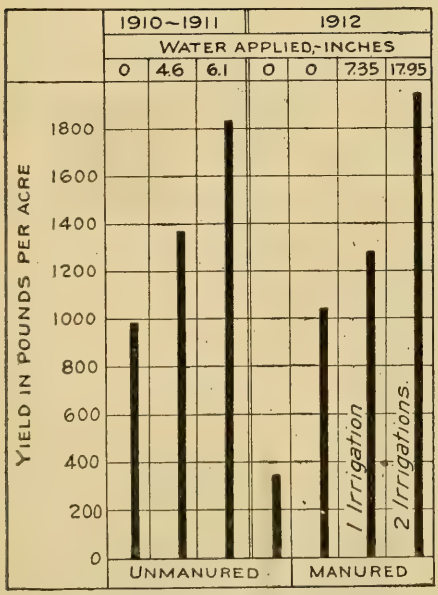

FIG. 4.—Yield of barley with different quantities of water, on manured and unmanured land.

It will be noted that in each of these seasons two irrigations, one of which was applied at about the time the grain came to a head or soon after, or one late irrigation, as in 1911, produced a heavy yield above the single early irrigation. In each of these three years strong, drying north winds occurred about the time the grain was in the dough. The unirrigated and early irrigated grain was badly pinched, while the presence of the moisture in the checks irrigated late seemed to prevent this, producing full, plump grain.

Were further conclusions to be drawn each season should be considered separately, but in each case inspection of the value column will show that for each of these three seasons irrigation of grain was made to pay.

IRRIGATION EXPERIMENTS WITH INDIAN AND EGYPTIAN CORN IN 1910 AND 1911.

For this work, which extended through 1910 and 1911, the 4-acre tract lying directly north of the west end of check 37 was used. During 1909 this tract was in sugar beets, and previous to that for a number of years it had been in grain.

In the spring of 1910 it was plowed twice—March 1 and April 9—harrowed, and cross-harrowed. On April 29 the west 2 acres were seeded to Yellow Dent Indian corn and the east half to Egyptian corn (white durra), a sorghum. In seeding a corn planter was used and the rows were placed 40 inches apart.

During the season of 1910 no definite time for irrigation was set or definite quantities assigned, both being controlled by the needs and conditions of the growing crops.

INDIAN CORN.

Immediately after planting the field was divided into four plats, the water being applied as shown in the following schedule:

Schedule of irrigation of Indian corn, 1910.

Number of plat.	Number of irrigations.	Date.	Depth applied.
			Inches.
1	None		
2	One	June 24	3.3
3	Two	do	3.3
		July 13	2.0
4	Three	May 26	4.4
		June 24	2.1
		July 13	1.5

Thorough cultivation followed each of these irrigations, and at all times the field was kept free from weeds. In the middle of August, when the corn was in the milk, it was cut, weighed, and fed green.

After the crop was removed the land was fall plowed, harrowed, and allowed to stand idle through the winter. The following March it was again plowed, harrowed, and seeded to "Yellow Flint" corn and the experiment of 1910 repeated. The area was divided into four plats, which received the following amounts of water during the growing season.

Schedule of irrigation of Indian corn, 1911.

Number of plat.	Number of irrigations.	Date.	Depth of water applied.	Status of corn.
			Inches.	
1	None			
2	One	June 22	2.3	Corn 20 inches high.
3	Two	June 21	2.2	Do.
		July 17	2.5	Corn coming in tassel.
4	Three	June 21	2.3	Corn 20 inches high.
		July 17	2.4	Corn coming in tassel.
		Aug. 8	2.4	Corn coming into the milk.

In each of these irrigations the furrow method was used, a small stream running in each furrow for a long period, thus avoiding flooding and, as in previous seasons, a thorough cultivation following each irrigation.

August 16 and 17 the corn was harvested, weighed, chopped, and stored for winter use.

The following table shows the results obtained for the two seasons:

Summary of results of irrigation of corn.

Season.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.	Value at $2.50 per ton.	Cost of irrigation.
			Inches.	*Tons.*		
1910	1	None		6.85	$17.13	
	2	One	3.3	8.85	22.13	$1.50
	3	Two	5.3	10.05	25.13	2.60
	4	Three	8.0	10.45	26.13	3.90
1911	1	None		3.67	9.18	
	2	One	3.0	4.86	12.15	1.40
	3	Two	4.8	5.21	13.03	2.45
	4	Three	7.1	6.59	16.48	3.65

NOTE.—Cost of irrigation taken at 30 cents per acre-inch for water and application, plus 50 cents per acre per irrigation for furrowing.

The most noticeable feature in these results is the decrease in yield in 1911, when compared with the yield in 1910. This is due entirely to the character of the season. The late spring of 1911 was abnormally cold and very unfavorable to the production of a good yield, even in the presence of an abundance of moisture.

During 1910 one and two irrigations were applied to advantage, while the third irrigation just before harvesting produced an increase of but 0.4 ton per acre green weight, and was applied at a loss.

The season of 1911 shows light yields and small increases, and if interest on the investment in pumping machinery and cost of leveling the land be added to the cost of irrigation no financial gain would be realized.

EGYPTIAN CORN.

This investigation followed along the same lines as the investigations with Indian corn, the preparation of the land, time of seeding, and entire procedure being the same up until the time of the first

irrigation. It was noticed, however, that the Egyptian corn (white durra) was much slower in coming up, and in the early stages of growth developed very slowly, especially during the cold spring weather of 1911.

The area originally was divided into three plats, No. 1 containing 0.9 acre; No. 2, 0.46 acre; and No. 3, 0.67 acre. About the middle of June it was seen that the yield from the unirrigated plat, No. 1, was going to be small, and it was then subdivided into plats 1–A, 1–B, and 1–C, of 0.3 acre each. Plat 1–A was not irrigated, plat 1–B received one irrigation, and plat 1–C two irrigations. Following are the dates of irrigation and the quantities of water applied:

Schedule of irrigation of Egyptian corn, 1910.

Number of plat.	Number of irrigations.	Date.	Depth.	Status of corn.
			Inches.	
1–A	None			
1–B	One	June 15	3.75	Corn 24 inches high.
1–C	Two	do	3.75	Do.
		July 14	1.75	Corn forming heads.
2	One	July 13	3.10	Do.
3	Two	May 28	3.25	Corn 4 inches high.
		July 14	2.10	Corn forming heads.

During 1911 the experiment was repeated on the same soil. The first seeding on April 18 was a failure, and only about one-fourth of a stand came up. The plat was replowed, harrowed, and reseeded May 13 and a good stand obtained. The area was then divided into four equal checks and the following irrigation schedule outlined:

Schedule of irrigation of Egyptian corn, 1911.

Number of plat.	Number of irrigations.	Date.	Depth.	Status of corn.
			Inches.	
1	None			
2	One	June 21	1.8	Corn 6 inches high.
3	Two	do	2.6	Do.
		July 18	2.0	First heads forming.
4	Three	June 22	2.3	Corn 6 inches high.
		July 18	1.9	First heads forming.
		Aug. 8	1.5	Corn in the dough.

In all irrigations the furrow method was practiced, the water being applied in alternate furrow spaces. A thorough cultivation followed each irrigation, and the whole area was kept free from weeds during both seasons.

In harvesting, which occurred the first of October, the heads were picked, hauled, and thrashed, and later the stalks were cut with a mowing machine.

The following table shows the results of the two seasons' work:

Summary of results of irrigation of Egyptian corn.

Season.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.	Value at $1.50 per 100 pounds.	Cost of irrigation.
			Inches.	*Pounds.*		
1910	1–A	None		1,335	$20.03	
	1–B	One	3.75	2,670	40.05	$1.52
	1–C	Two	5.50	2,700	40.50	2.65
	2	One	3.10	2,510	37.65	1.43
	3	Two	5.35	3,340	50.10	2.60
1911	1	None		1,100	16.50	
	2	One	1.8	1,690	25.35	1.04
	3	Two	4.6	2,650	39.75	2.38
	4	Three	5.7	2,965	44.48	3.20

NOTE.—Cost of irrigation is taken as 30 cents per acre-inch for power and attendance, plus 50 cents per acre per irrigation for furrowing.

The accompanying diagram (fig. 5) shows the results for 1911, platted graphically, the yields with the corresponding amounts of water applied being shown.

With this crop, as with the Indian corn, a greater yield is produced in 1910, with less amounts of water applied, than in 1911, due entirely to a warmer spring and much more favorable growing season.

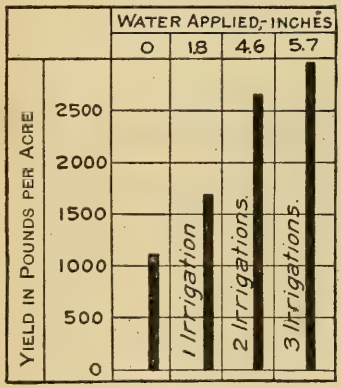

FIG. 5.—Yield of Egyptian corn with different quantities of water.

The results for 1910 show but a small variation in the yields from plats 1–B, 1–C, and 2, and a large increase in plat 3. This is due to the time of irrigation, plat 3 receiving one early and one midseason irrigation, the first applied before any effects of drought were shown, thus keeping more or less of a constant moisture percentage in the soil during the entire period of growth. In 1911 the yields increased quite uniformly with the increased amounts of water applied, until the third irrigation, when there was a slight falling off. When this last irrigation was applied the heads were fully formed and the grain ripening, and the only effect of this irrigation was probably in preventing any pinching or shrinking in the grain.

Inspection of the value column for each season shows that the irrigation of this crop may be made to pay, even if 6 per cent interest on an investment of $50 per acre for leveling the land and developing water be added to the cost of irrigation.

Here, as in the irrigation of other grain crops, no definite duty of water can be established. The amounts of water required and the time of irrigation will always vary with the season, and the intelli-

gence of the irrigator along these lines is always going to be the controlling factor in success and failure or profit and loss. That the time of applying water is of as great importance as the quantity of water applied is shown plainly in 1910, in plat 1–C, where two irrigations followed in close succession and the increase in yield due to the second irrigation did not pay for the cost of the irrigation.

IRRIGATION AND CROP ROTATION EXPERIMENTS IN 1912.

It was decided in the fall of 1911 to turn under a part of the alfalfa as green manure, and in the spring of 1912 to start a crop rotation of grain, sugar beets, corn, and potatoes, following alfalfa, these crops to be investigated from an irrigation standpoint, showing the increase in yield, with the increased amounts of water applied. Comparison also was to be made with the returns obtained from the unfertilized soils in previous years.

Early in November, 1911, plats 1 to 15 and 32 to 37 were plowed to a depth of 8 inches with a two-gang plow. At this time the alfalfa had about a 6-inch top growth, and a good covering of green manure was turned under. Following this plowing the land was harrowed, cross-harrowed, and disked, leaving it in a finely pulverized condition to receive the winter rains.

On February 1, 1912, the land was replowed to a depth of 6 inches, harrowed, and cross-harrowed. Owing to the light winter rains the green manure had not thoroughly rotted, although the soil turned up in a fine, mellow condition, presenting the appearance of recently having been given a heavy application of rotted stable manure.

Owing to the checking system of plats 1 to 15, it was necessary to relevel them for furrow irrigation. This area was later seeded to sugar beets, Indian corn, and Egyptian corn.

GRAIN FOLLOWING ALFALFA.

Following the replowing and harrowing on February 1, the east halves of checks 32, 33, and 34 were seeded to 60-day oats, 75 pounds of seed per acre being planted. At the same time the west halves of these checks were seeded to Australian white wheat, at the rate of 85 pounds of seed per acre. All of the seed was drilled in, the drills running lengthwise with the checks, and a good stand came up on all of the checks.

The following plan of irrigation was outlined and carried out:

Schedule of irrigation of grain following alfalfa in 1912.

OATS.

Number of plat.	Number of irrigations.	Date.	Depth.	Status of oats.
			Inches.	
32	None			
33	One	April 9	13.2	Oats 12 inches high.
34	Two	April 13	13.2	Do.
		May 10	7.2	Oats heading out.

WHEAT.

32	None			
33	One	April 25	10.00	Wheat 24 inches high.
34	Two	April 15	9.15	Wheat 18 inches high.
		May 9	8.40	Wheat coming into full head.

In each irrigation water was added at a time when it was thought that the best results would be obtained, and in no case was irrigation delayed until the crop was suffering for moisture. It will be noticed that in all cases large amounts of water were used. This was necessary in order to cover the checks completely and was due to the open, porous condition of the soil, the result of turning under the green manure.

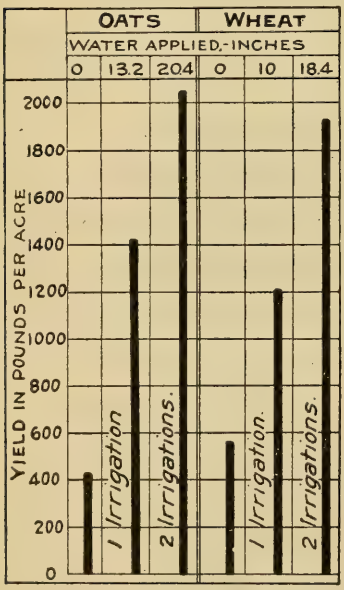

FIG. 6.—Yield of oats and wheat, with different quantities of water.

Early in June, just before harvesting, several days of heavy north wind occurred, badly shattering both crops, and it was estimated that 30 to 40 per cent of the grain was lost. This loss is not included in the table of yields. June 15 all plats were cut with a binder, stacked in the field, and later thrashed with a stationary thrasher.

The table following shows the yields in hay and grain in pounds per acre, the quantity of water applied, and the cost of irrigation. The accompanying diagram (fig. 6) shows the yields of grain platted with the corresponding amounts of water applied to each check.

Summary of results of oats and wheat irrigation.

Crop.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.		Percentage of grain.	Grain value at $1.50 per 100 pounds.	Cost of irrigation
				Hay.	Grain.			
			Inches.	*Pounds.*	*Pounds.*	*Per cent.*		
Oats	32	None		1,380	435	31.8	$6.53	
	33	One	13.2	4,900	1,420	28.0	21.30	$3.96
	34	Two	20.4	5,820	2,040	35.1	30.60	6.12
Wheat	32	None		1,730	560	32.4	8.40	
	33	One	10.0	3,920	1,210	30.9	18.15	3.00
	34	Two	18.4	6,300	1,935	30.8	29.03	5.52

NOTE.—Irrigation cost figured at 30 cents per acre-inch for power and attendance.

With the oats the single irrigation of 13.2 inches increased the yield 225 per cent, giving a gain in returns of $14.77 per acre, at a cost of $3.96 per acre for irrigation. Two irrigations, totaling 20.4 inches, increased the yield 370 per cent, with a gain of $24.07 per acre in grain value, at a total cost of $6.12 per acre for water and attendance during irrigation.

Figuring on the same basis with the wheat, one irrigation of 10 inches increased the yield 116 per cent, with a gain in returns of $9.55 per acre, at a total increased cost of $3 per acre. Two irrigations increased the yield 245 per cent, giving an increase in returns of $20.63 per acre, at a total expense of $5.52 per acre.

It will also be noted that in all cases the percentage of grain to hay remains about the same, showing the grain production to increase uniformly with the total weight of matter produced.

No definite conclusions can be drawn from this one season's work. A decided advantage, nevertheless, is shown in favor of irrigation. All of the water was applied at a financial gain, and an idea is obtained of what may be accomplished in years of light rainfall when conditions are unfavorable to dry-land farming.

SUGAR BEETS FOLLOWING ALFALFA.

Following the early spring preparation of checks 1 to 15, the land was replowed on February 22, then harrowed and cross-harrowed. The area was divided into seven plats, 5, 6, and 7 to be seeded early, and 1, 2, 3, and 4 seeded later. March 11 the first plats were seeded in drills 20 inches apart, 15 pounds of Wankaka seed per acre being used. March 27 the remaining checks were seeded in the same manner. Spacing, thinning, and hoeing followed when the beets were in the third and fourth leaf, and this was followed by a thorough cultivation.

The dates of irrigation depended upon the needs of the crop, and sufficient water was added to give the soil a thorough wetting. The furrow method of irrigation was practiced, the water being applied in alternate spaces between the rows, and as nearly as possible the water was confined to the furrows and kept away from the beets.

As long as the size of the beets permitted, thorough cultivation followed each irrigation, and all plats were kept free from weeds.

Following are the dates of irrigation and the amounts of water applied:

Schedule of irrigation of sugar beets in 1912.

Time of seeding.	Number of plat.	Number of irrigations.	Date.	Depth applied.
				Inches.
Early—Mar. 11	5	None		
	6	One	May 21	10.5
	7	Two	May 21	9.2
			June 21	4.4
Later—Mar. 27	1	None		
	2	One	May 24	6.12
	3	Two	May 26	6.12
			June 21	5.40
	4	Three	May 24	6.12
			June 21	5.40
			July 17	5.28

All plats were harvested the last of August, being plowed, topped, and sold in the field. At this time average samples were taken from each plat and tests made for sugar percentage and purity.

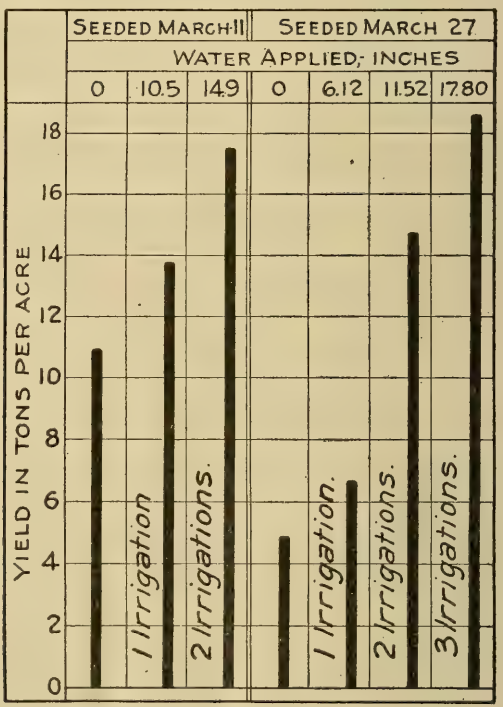

FIG. 7.—Yield of sugar beets, seeded at two periods and irrigated with different quantities of water.

The table following shows the results in yield, sugar percentages, purity, and net returns per acre. These results are illustrated in figure 7, the yields and corresponding amounts of water applied being shown.

Yield of sugar beets and percentage of sugar content and purity.

Seeding.	Number of plat.	Number of irrigations.	Depth.	Sugar content.	Purity.	Yield per acre.	Value at $5 per ton.	Cost of irrigation.
			Inches.	*Per cent.*	*Per cent.*	*Tons.*		
Mar. 11	5	None		21.3	88.13	10.85	$54.25	
	6	One	10.5	17.7	80.96	13.80	69.00	$4.10
	7	Two	14.9	16.5	81.44	17.50	87.50	5.81
Mar. 27	1	None		23.00	83.14	4.85	24.25	
	2	One	6.12	20.10	83.75	6.70	33.50	2.38
	3	Two	11.52	17.25	83.89	14.75	73.75	4.49
	4	Three	17.80	16.85	89.91	18.60	93.00	6.94

In irrigating, continual attendance was necessary at a cost of 25 cents per acre-inch. Power cost 14 cents per acre-inch. The total cost is therefore 39 cents per acre-inch.

With the same number of irrigations heavier yields were obtained by early seeding than by late seeding. The results show an increase in yield of 6 tons per acre from the unirrigated plats in favor of the early planting, while the plats given one irrigation show an increase of 7.10 tons per acre. This is due entirely to the weather conditions following seeding. Between March 12 and 15, 1.13 inches of rain fell, giving the early seeding a vigorous start. Following this no more rain fell until April 10, and the late seeding was very slow in sprouting, some of the seed not coming up until the middle of April, after the early seeded plats had been thinned.

In general the sugar percentage decreased with the increased amounts of water added, although in every case this decrease was overbalanced by the increase in yield.

The time of irrigation and the quantity of water required will always depend upon the local conditions. This is shown very clearly in the yields from plats 2 and 3, on which a second irrigation of 5.4 inches, costing $2.10 per acre, increased the yield 120 per cent and the gross returns $40.25 per acre. Here, as in other irrigated crops, success or failure lies in the judgment of the irrigator in applying the water.

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Contribution from the Forest Service, Henry S. Graves, Forester.

January 23, 1914.

FOREST MANAGEMENT OF LOBLOLLY PINE IN DELAWARE, MARYLAND, AND VIRGINIA.

By W. D. Sterrett, *Forest Examiner.*

LOBLOLLY PINE ADAPTED TO FOREST MANAGEMENT.

Forestry or forest management differs from ordinary lumbering in that when a mature stand of timber is cut provision is always made to secure a new crop of young seedlings—either by natural seeding or by sowing or planting—to take the place of the trees removed. It consists primarily in the growing of successive crops of timber on the same area. It includes also the care of immature stands, comprising chiefly improvement thinnings and protection from fire.

Loblolly pine is easily the leading tree for forest management in those portions of Maryland, Delaware, and Virginia where it grows naturally. The factors which combine to make it particularly suitable for commercial timber growing are: The ease with which it reproduces itself and forms pure, well-stocked stands; its rapid growth and the wide range of sites on which it will grow; the many uses to which its wood is adapted; the comparative cheapness of logging and milling the timber, and the good prices which its lumber commands. This bulletin aims to show the financial possibilities in growing loblolly pine in Maryland, Delaware, and Virginia and to describe the best methods of management. As a basis for the latter the silvicultural characteristics of the species are first discussed.

DISTRIBUTION AND IMPORTANCE.

The accompanying map (fig. 1) shows the botanical and commercial distribution of loblolly pine in Delaware, Maryland, and Virginia. The region to which this report applies is that covered by the botanical range of the species. In this region loblolly pine occurs naturally in some 60 counties, comprising an area of 21,100 square miles (13,500,000 acres). Table 1 [1] gives the total cut of lumber of

[1] Given in detail by counties in Table 22, Appendix B.

all species and that of yellow pine in these counties in 1909, and an estimate of the proportion which loblolly formed of the yellow pine output.

TABLE 1.—*Cut of lumber in 60 counties of Delaware, Maryland, and Virginia in 1909.*

State.	Cut of all species, M b. f.	Cut of yellow pine.		Proportion of yellow pine output cut from loblolly pine.
		M b. f.	Per cent of total.	
Delaware (2 counties; 135 square miles)	51,967	38,767	74.6	90 per cent loblolly.
Maryland (13 counties; 440 square miles)	143,540	97,975	68.2	80 per cent loblolly.
Virginia (45 counties; 1,250 square miles)	1,295,353	1,116,334	86.2	75 per cent loblolly.
Total (1,825 square miles)	1,490,860	1,253,076	84.1	

As seen from the table, yellow pine forms the bulk of the lumber output, and is in turn composed chiefly of loblolly.

FOREST TYPES.

Loblolly pine occurs, even in the same locality, in a number of forest types arising from differences in physiography and soil. Five-sixths of the region, including all of the Maryland and Delaware portions and the larger part of the area in Virginia, lies in the comparatively flat coastal plains or "tidewater" region, with an average elevation of about 100 feet above sea, and containing much wet, poorly drained land. The remaining one-sixth is in the eastern part of the well-drained rolling hill country or Piedmont section of middle Virginia, with an elevation varying from 100 to 500 feet. The soils in the Coastal Plain section are generally light, while those in the Piedmont are heavy.

COASTAL PLAIN TYPES.

In the tidewater section loblolly pine grows:

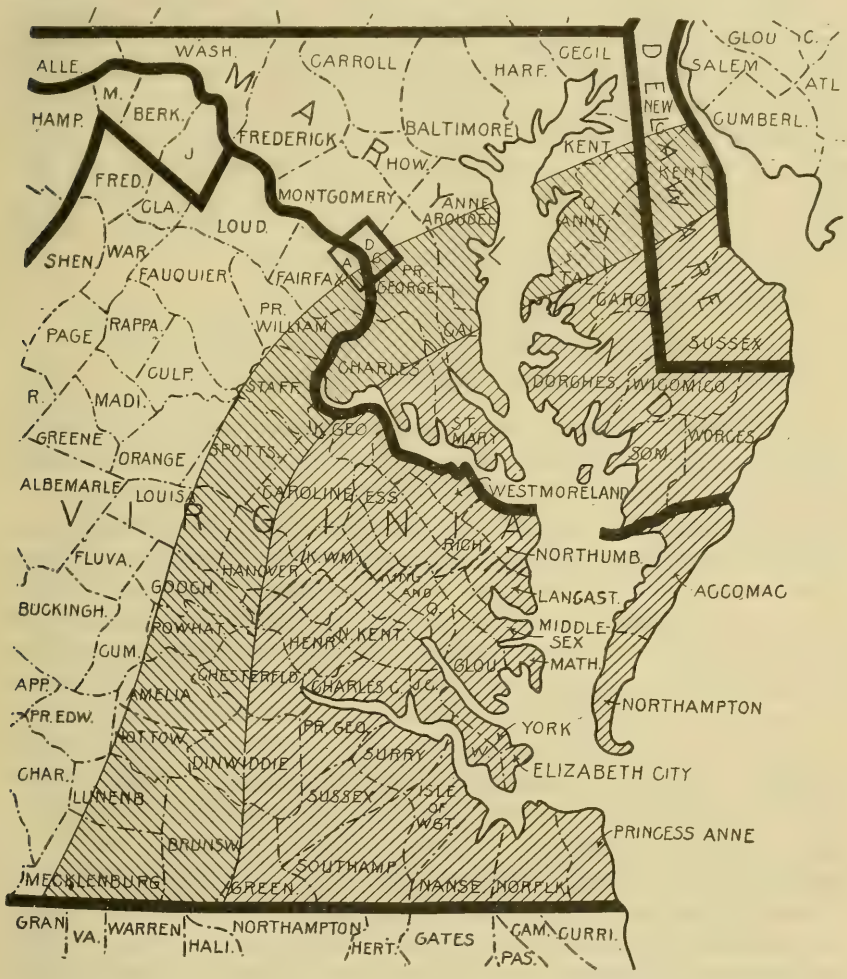
(1) In pure stands: (*a*) on old fields, where most of the pure stands of any extent are found; (*b*) on moist soils along the edges of swamps, streams, and ponds, usually in comparatively small groups.

(2) In mixture with other species in swamps or semiswamps; (*a*) with cypress, gum, and maple on very wet land subject to overflow; (*b*) with maple, gum, several species of oak, and yellow poplar on moist to wet land not subject to inundation.

(3) On well-drained or upland soils in mixture with oaks, hickory, cedar, and gum, and shortleaf, scrub, and pitch pines.

In the Virginia tidewater section, covering some 11,000 square miles (7,000,000 acres), loblolly is the only species of pine occurring to any extent in commercial quantities, and is the important timber tree. In the northern half of the Maryland-Delaware Coastal Plain

section loblolly is comparatively scarce, growing in mixture with hardwoods and some scrub and pitch pine, and is not important commercially. In the southern half of this region, however, where the general elevation is less than 50 feet above sea, loblolly is the most important timber tree.



Regions of commercial importance. Limits of botanical distribution.

FIG. 1.—Distribution of loblolly pine in Maryland, Delaware, and Virginia.

PIEDMONT TYPES.

In middle or Piedmont Virginia, in the portion contiguous to the western edge of the Coastal Plain region, from Fredericksburg south, loblolly pine occurs in the following types:

(1) In pure pine stands (chiefly on old fields) in mixture with shortleaf and scrub pines. Shortleaf usually predominates, though

on lower slopes loblolly sometimes does. Westward from the eastern edge of the Piedmont, loblolly is gradually displaced by shortleaf and scrub pine, until the western limits of its botanical distribution are reached. (See map, fig. 1.)

(2) (*a*) In mixed pine and hardwood stands on lower slopes and on well-drained bottoms. In the original forests loblolly pine is rarely found, even as stray individual trees. The forests of this type are composed of white oak, yellow poplar, red oak, ash, birch, hickory, walnut, and red maple. (*b*) In mixed pine and hardwood stands on the uplands. The original forest is a mixture of oak, hickory, black gum and pine—usually shortleaf, some scrub, and infrequently loblolly, the last as a rule occurring only where the soil is fairly moist. Where loblolly pine occurs in middle Virginia it is usually a tree of secondary importance, although occasionally on old fields it is found to limited extent in pure or nearly pure stands.

CHARACTERISTICS OF LOBLOLLY PINE.

SOIL, MOISTURE, AND LIGHT REQUIREMENTS.

Loblolly pine is not fastidious in its soil requirements, and grows on a great variety of sites. It is in fact adapted to a wider range of soil conditions than any of the pines with which it is associated, though it grows best on deep, moist, well-drained, porous soils.

The tree depends much more upon soil moisture than upon atmospheric moisture, and in fact throughout its range in the United States it is most abundant in regions of lesser precipitation. It grows on soils with all the different degrees of moisture content from wet swamps to dry sandy uplands. It prefers, however, the intermediate flat, moist lands, edges of swamps, and well-drained bottoms, where it is best able to hold its own in competition with other species, and to which virgin stands are almost exclusively confined. Because of its superior reproductive power loblolly has extended itself as second-growth over large areas of comparatively dry upland soils, both heavy and light, where it was rarely found in the original forest.

Loblolly pine is intolerant of shade, being intermediate in its light requirements between the less tolerant longleaf and the more tolerant scrub pine. The effects, on different sites, of its light requirements upon reproduction and the development of individual trees and of stands are discussed later.

FORM AND DEVELOPMENT.

Under favorable forest conditions, with plenty of overhead light but shaded on the sides, loblolly pine develops, by the time it is 50 to 100 years old, a long, straight, cylindrical bole, clear of limbs for from 50 to 75 feet, with a diameter of from 15 to 24 inches breast-high and a height of from 80 to 120 feet. During the period of rapid

height growth, which continues until the tree is about 40 years old, loblolly pine has a long, broad, conical or ovoid crown. With increasing age this gradually dies off at the bottom, and finally becomes somewhat flat and irregular.

In comparatively dense stands loblolly pine prunes itself rapidly, because of its intolerance of shade, and develops long, straight and clear boles which produce lumber of the best grades. In open stands, on the other hand, large, wide-spreading lateral branches are developed, and knotty, low-grade lumber is the result. Comparatively open stands characterize the dry soils, on which natural thinning is more rapid and the trees produced are shorter and less clean-boled than on moist situations.

Growth and Yield per Acre.

The rate of growth of loblolly pine varies considerably with the quality of the soil. The different soils or sites on which it commonly occurs may be conveniently grouped under three quality classes—I, II, and III.

Quality Class I comprises the richest soils, where the rate of growth is most rapid. It includes the very fertile soils, usually rich in organic matter, with a uniformly abundant supply of moisture, but free from standing water, such as bottom land along the edges of streams, ponds, and deep swamps, moist depressions and basins and the very best old-field soils.

Quality Class II includes the great bulk of soils on which the species occurs. These are fairly moist and are found in broad stretches of flat land between the bottoms and the uplands and in most of the old fields.

Quality Class III includes all poor and dry upland soils, both heavy and light, dry and sandy flat-land soils and sand hillls, and the poorest of wornout old-field land.

Old growth loblolly trees occur almost exclusively as single individuals or in small groups in mixture with other species. In second growth following clean cutting and on abandoned fields, however the species has a remarkable tendency to reproduce itself in pure, even-aged, fully stocked stands. Table 2 indicates the rate of growth of such stands and the trees composing them on the three qualities of soil described, including the possbile yield in either cubic feet or board feet at different ages. The cubic-foot yields are given for trees 3 inches in diameter and over, either peeled or with the bark on. The board-foot yields, which, of course, are not in addition to the cubic-foot yields, but merely express the yield for the same stand in another unit, apply when either all trees over 5 inches or all over 7 inches in diameter are counted. This table is based on measurements taken of pure, even-aged, unmanaged, fully stocked stands, found

chiefly on old fields, and is a conservative indication of the possible yields from properly managed stands.

TABLE 2.—*Rate of growth and yield of pure, even-aged, fully stocked, unmanaged stands of loblolly pine in Somerset and Worcester Counties, Md.*

Age.	Trees per acre.		Average height of predominant[1] trees.	Average diameter breasthigh.		Yield per acre.			
	Dominant.	Total.		Dominant trees.	All trees.	Trees 3 inches and over in diameter (peeled).	Trees 3 inches and over in diameter (with bark).	Trees 5 inches and over in diameter.	Trees 7 inches and over in diameter.
	QUALITY I.								
Years.	*No.*	*No.*	*Feet.*	*Inches.*	*Inches.*	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*
10	1,051	1,403	27	3.8	3.5	1,020	1,600	1,200	.....
15	742	1,071	44	5.4	4.8	1,610	2,390	4,700	1,400
20	540	827	55	6.8	6.0	2,250	3,200	8,300	5,200
25	411	611	63	8.1	7.1	2,900	4,000	12,100	9,900
30	343	469	69	9.1	8.2	3,570	4,780	15,900	14,600
35	290	387	74	10.1	9.1	4,230	5,570	19,700	19,100
40	253	325	78	11.0	10.0	4,920	6,380	23,800	23,800
45	223	278	83	11.9	10.9	5,620	7,200	28,100	28,100
50	201	244	87	12.7	11.7	6,350	8,050	32,600	32,600
	QUALITY II.								
10	1,095	1,518	21	3.4	3.2	670	1,070	400	.....
15	738	1,099	34	4.8	4.3	1,110	1,680	2,800	800
20	527	758	44	6.1	5.5	1,600	2,320	5,400	3,000
25	381	587	51	7.4	6.5	2,140	3,000	8,100	6,200
30	293	475	57	8.6	7.4	2,700	3,690	11,000	9,400
35	241	413	62	9.6	8.1	3,270	4,390	13,800	12,400
40	210	385	66	10.4	8.6	3,840	5,100	16,600	15,400
45	189	354	70	11.1	9.1	4,430	5,830	19,500	18,700
50	174	344	73	11.7	9.4	5,040	6,600	22,600	22,600
	QUALITY III.								
10	576	827	15	3.3	3.1	340	550	.....	.....
15	656	1,089	25	4.2	3.8	630	980	1,300	200
20	625	1,075	33	5.0	4.4	960	1,460	2,800	900
25	538	894	40	5.8	5.1	1,360	2,000	4,400	2,100
30	480	751	46	6.4	5.7	1,790	2,580	6,000	3,500
35	407	610	50	7.1	6.4	2,280	3,200	7,700	5,500
40	353	517	54	7.7	7.0	2,770	3,820	9,400	7,600
45	309	441	57	8.3	7.6	3,290	4,480	11,300	10,200
50	280	381	60	8.8	8.2	3,860	5,180	13,400	13,400

[1] Predominant trees are considered to be those composing a group of the largest dominant trees, the basal area of the group being equal to one-third of the basal area of all the dominant trees.

REPRODUCTION.

In ability to reproduce itself loblolly is one of the best, if not the best, of any of the pines in the eastern United States.

SEED PRODUCTION AND DISSEMINATION.

In comparison with other species of pine loblolly is very prolific in seed production. Some seed is produced every year, but the amount varies considerably. Heavy seed years occur at intervals of

from 3 to 5 years. In some years hardly sufficient seed is produced to give adequate reproduction. Loblolly takes two seasons to ripen its cones, and because of this the relative amount of seed which will be produced can be foretold a year in advance. The amount of seed produced by any one tree varies normally with its age, size, and amount of growing space. The best seeders are trees 40 or more years old, or which have about completed their principal height growth and which have comparatively isolated crowns and an ample growing space. Trees in crowded stands do not seed so prolifically as trees growing in the open.

The seed falls in late autumn and through the winter and early spring. It is disseminated chiefly by the wind. Trees with many cones will scatter seeds very plentifully to a distance of twice their own height in the direction of the prevailing winter winds. In general loblolly pine can be relied upon for thickly stocking in one season unobstructed areas adjacent to seed trees for a distance of 100 feet to 100 yards, according to the height of the trees and provided it is a good seed year and there is a suitable seed bed.

Seed-bed Requirements.

For germination loblolly pine seed is comparatively independent of seed bed and soil conditions. The seed requires only a slight degree of moisture to cause it to germinate. For seedling establishment and growth following germination the seed-bed requirements of loblolly vary with the moisture content of the soil. On fresh to dry soils the seedling demands an open seed bed—that is, with plenty of light and little or no overhead crown cover and the soil exposed, or nearly so, with no layer of leaves and litter to prevent the developing roots from immediately coming in contact with the soil. On moist to wet sites, on the other hand, the seedling is able to exist and develop under considerable shade on comparatively thick layers of undecomposed pine needles and litter.

The most favorable conditions for loblolly reproduction are, in general, found in the open on an exposed loose soil, into which the roots of the seedling can at once enter and where the crown has plenty of light. Where loblolly pine seed trees occur in the vicinity of unused fields the land very quickly becomes seeded up to pine. Loblolly reproduction also takes place readily on a cover of grass, provided it does not form a compact sod. It seeds well on areas covered with tall grass, such as broom grass, which may come in after the forest is cleared.

On dry sites in the forest with a thick layer of undecomposed leaf litter there is little chance for reproduction of loblolly because of inadequate moisture, but on moist to wet situations reproduction

usually takes place in spite of any impeding forest floor. On dry sites the seedling requires a good deal more light for its development or existence even than on moist to wet situations, which is one of the main reasons for the lack of loblolly reproduction under the shade of large trees, where the soil is not moist. For this reason lumbering as a rule improves the seed-bed conditions for loblolly pine and increases its reproduction, provided seed trees of the species are left. The abundance of direct sunlight let in by cutting of the forest also causes the impeding forest floor to decompose rapidly, so that the roots of the seedlings can more readily reach the soil. Another great hindrance to germination and growth of loblolly-pine seed which falls after lumbering, in addition to that of a thick undecomposed forest floor, is a luxuriant growth of ground cover and underbrush, including hardwood sprouts and seedlings, which in places may be so dense as to preclude pine reproduction entirely.

Seedling Development.

The growth in height of loblolly seedlings for the first two years is slow, but during this period there is vigorous root development. Under average conditions seedlings in the open reach a height of from 2 to 6 inches the first and from 6 to 12 inches the second season. After this there sets in a rapid height growth of from 1 to 3 feet a year, which continues for from 30 to 50 years before beginning to fall off.

SUSCEPTIBILITY TO INJURY.

Wind.

Loblolly pine is usually windfirm, since it grows mainly on soils conducive to the development of a deep taproot with strong laterals. It is only where there is an impenetrable subsoil that it develops a shallow, flat root system and is easily wind-thrown. It seldom suffers much damage from windbreak, and where broken off will usually show that it has first been killed or weakened by fire, insects, or fungi.

Fire.

The thick bark of loblolly pine gives it unusually good protection from damage by surface fires. Table 3 shows the average thickness of bark for trees of different diameters and heights 20 to 50 years old, which indicates their relative susceptibility to damage.

FIG. 1.—DENSE 8-YEAR-OLD STAND ON COMPARATIVELY MOIST SITE.

FIG. 2.—OPEN STAND OF SAME AGE ON VERY DRY SANDY SITE A FEW FEET AWAY.

EFFECT OF MOISTURE ON DENSITY OF STAND.

TABLE 3.—*Average thickness of bark at 4.5 feet from the ground for trees of different diameters and heights, from 20 to 50 years in age, Somerset and Worcester Counties, Md.*

[Table based on taper curves.]

Diameter breast-high.	Height of tree (feet).						Diameter breast-high.	Height of tree (feet).					
	30	40	50	60	70	80		30	40	50	60	70	80
	Double width of bark at breastheight.							Double width of bark at breastheight.					
Inches.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Inches.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
3	0.5	0.7	.....	.....	.....	.....	12	.....	.....	1.7	1.6	1.4	1.3
4	.7	.8	0.9	.....	.....	.....	13	.....	.....	1.8	1.7	1.5	1.4
5	.9	.9	1.0	.....	.....	.....	14	.....	.....	.....	1.9	1.6	1.5
6	1.0	1.0	1.1	1.1	.....	.....	15	.....	.....	.....	1.9	1.7	1.5
7	1.1	1.2	1.2	1.2	.....	.....	16	.....	.....	.....	2.1	1.9	1.6
8	1.3	1.3	1.3	1.3	1.2	.....	17	.....	.....	.....	.....	2.0	1.7
9	.....	1.5	1.4	1.3	1.2	.....	18	.....	.....	.....	.....	2.1	1.9
10	.....	1.6	1.5	1.4	1.3	1.2	19	.....	.....	.....	.....	.....	2.0
11	.....	.....	1.6	1.5	1.3	1.2	20	.....	.....	.....	.....	.....	2.1

By far the most common form of fire in loblolly pine is the surface fire. The damage to any particular stand varies with the severity of the fire and the age and size of the trees. In general, the older the stand and the larger the trees the less will the damage be. Even a light surface fire in a sapling stand under 6 years of age usually kills a large part if not all of the trees outright, while in an older stand such a fire would kill few or none of the trees. Fires in sapling stands are especially destructive because they are likely to spread to the tops. Crown fires in loblolly pine, however, are limited almost entirely to the younger sapling stands, because of the rapidity with which older trees prune themselves of lateral branches for a considerable distance above the ground. The most destructive and costly form of fire in loblolly pine is a combination of surface and ground or subsurface fire, such as occurs at very dry times in bottoms and swamps where there is a deep accumulation of partially decomposed vegetable matter. Such fires kill the largest trees as well as the smallest.

The severity of forest fires and the consequent damage varies with a number of factors, among them the amount and relative dryness of inflammable material, such as leaf litter, débris, and underbrush, the velocity of the wind, and the moisture content of the atmosphere. Stands on low, wet sites are less subject to damage by fire than those on dry situations.

It is a common practice of some lumber companies in the South to burn over the forest every one to three years to prevent the accumulation of inflammable material. Large areas of forest land in the South are also burned over annually to improve the grazing, which also prevents severe fires. This is a cheap and effective method of insuring protection to valuable mature standing timber, but is extremely harmful to young stands. Forest fires of any kind

are always injurious. Even if they do not kill the trees outright, they impair their vitality, lessen the rate of growth, and render them more susceptible to fatal attacks of destructive insects.

Insects.

The only insect enemy of loblolly pine to cause any serious damage in recent years is the southern pine beetle (*Dendroctonus frontalis*). It is important that this insect be watched for in stands under management. Whenever detected, steps should at once be taken to keep it under control. Apparently at long intervals, frequently of 20 years, it becomes so abundant as to cause widespread destruction of pine timber, a loss which could be averted in stands under management by proper precautions. The depredations frequently last several years unless measures are taken to control the insects. Other species of insects often follow in the wake of the Dendroctonus and feed on trees weakened or killed by its attacks. Sometimes they even attack and kill healthy uninfested trees in the same locality. But with the disappearance of the Dendroctonus in any particular locality the other species of beetles disappear also. This does not seem to be due so much to the measures taken to control the Dendroctonus as to the fact that these other insects are unable effectively to attack live pine timber unaided. However, though the southern pine beetle is the only insect causing serious damage to southern pines at present, it is possible that other species might sometimes become sufficiently numerous to cause extensive destruction.[1]

Whenever owners of loblolly-pine forests discover their timber to be dying in small patches and are unable to determine the cause, they should at once communicate with the Bureau of Entomology, U. S. Department of Agriculture.

Diseases.

The principal disease to which loblolly pine is subject is that which causes red heart. Mycelia (spawn) of large polyporous fungi infest the woody tissue of the living tree, the hyphæ (filaments) of the spawn destroying the walls of the wood cells, causing the wood to assume a reddish color and rendering it very brittle. Red heart is very rare in young loblolly pine—that is, under 75 years of age—but is quite common in old-growth trees from 150 to 200 years old. From the standpoint of future forest management this disease does

[1] For a complete discussion of how to detect insect injury by the southern pine beetle and methods of controlling infestations the reader is referred to Farmers' Bulletin 476, U. S. Department of Agriculture, by Dr. A. D. Hopkins, in charge of Forest Insect Investigations, Bureau of Entomology. Everyone managing loblolly pine forests should secure this bulletin. During 1910 and 1911 the Dendroctonus destroyed a considerable amount of pine timber in the South, though the insect has now been largely brought under control wherever owners of pine tracts have carried out the measures recommended in the publication.

not need to be considered, since future stands will be grown almost exclusively on short rotations of less than 75 years. The red heart grades (culls) of North Carolina pine lumber, provided for by the grading rules of the North Carolina Pine Association, will be of no importance after the old-growth timber is cut.

UTILIZATION.[1]

USES.[2]

Both the use and value of loblolly pine lumber have increased since the custom of seasoning it in dry kilns became common. Prior to that time loblolly lumber frequently went to the market green or imperfectly seasoned. It is largely sapwood, especially in small and medium-sized trees, and the water in it made it susceptible to attack by fungi, which gave a blue color to the wood, and not only marred its appearance but induced deterioration. Thorough drying in kilns removed the cause for that objection, and loblolly speedily won an important place in the market. Its range of uses is wide, and it is sold throughout the eastern and central United States and exported to Europe and Central America.

The principal uses to which loblolly pine is put are: For building lumber, such as interior finish, flooring, ceiling, frames and sashes, wainscoting, weather boarding, joists, lath, and shingles; for boxes and packages, in the form of boards and veneers, and in the manufacture of slack barrels; in the manufacture of cheap furniture, woodenware, toys, etc.; for construction purposes, in bridge and trestle work, in heavy building operations where the conditions are not such as to require longleaf, and in car construction, chiefly for freight cars. Much loblolly pine is cut for crossties, for which it is well suited after being given a preservative treatment. It is among the most easily treated timbers in the United States, and the recent developments in wood impregnation processes and plants is rapidly increasing its use for many purposes. It is extensively used for mine props in the South and in Pennsylvania, frequently after being given a preservative treatment. Few pines if any exceed loblolly in use for fuel. Immense quantities are shipped as cordwood for domestic purposes, and find markets in towns in the loblolly region and in cities as far north as Philadelphia. Its use for fuel purposes in manufacturing is also extremely large, particularly in brick burning, pottery kilns, and by bakers who demand a quick, hot fire.

A report of the woods used in Maryland for manufacturing purposes in 1909 [3] shows loblolly as exceeding all other woods combined (17

[1] For characteristics of the wood see Appendix C.

[2] Based on pp. 22–24, Bulletin 99 of the Forest Service, "Uses of Commercial Woods of the United States: Pines."

[3] The latest available figures.

species were used) in the manufacture of boxes and crates, and as standing second in cooperage and basket making. Among the many commodities of which it forms all or a part of the material are basket bottoms, vegetable crates, nail kegs, and boxes for fruits, vegetables, and bottles. It has a regular place in vehicle manufacturing for beds and bodies for wagons and carts, and in boat building for masts, siding, decking, lining, ceiling, cabins, and all kinds of finish and joiner work in skiffs, yachts, motor boats, and sailing craft. It is widely used by slack coopers. It is standard material for interior finish, and is frequently employed on an equal footing with long-leaf pine, which it closely resembles if carefully selected with regard to grain. It takes finish well, and if painted, as it usually is when used as weatherboarding, it wears well and needs repainting only at long intervals. It makes excellent flooring, and serves for practically all kinds of interior finish—window and door frames, ceiling, wainscoting, molding, railing, balusters, brackets, and stair work. Cabinetmakers work it into many articles, and it is seen in wardrobes, clothespresses, shelving, drawers, compartments, and boxes. It has no less a range of uses in furniture making, going for the most part into frames for couches, lounges, and large chairs.

A report of the wood-using industries of North Carolina (where conditions are like those in Virginia), in 1909, showed the position of loblolly pine to be similar to that in Maryland. In North Carolina more of it was used than of all other woods combined, the total being considerably more than 300 million feet. Practically every industry of the State that employed wood in manufacturing gave a prominent place to loblolly pine. Nearly 3,000,000 feet were used for telephone cross arms, it being practically the only wood employed for that purpose in the region. A comparatively large use in North Carolina is for tobacco hogsheads. Also, most of the matched flooring manufactured in that State was from loblolly.

There are a number of possible ways [1] of profitably utilizing loblolly pine material which at present it is not possible or will not pay to turn into lumber. Among these are the manufacture of wood pulp and paper, the manufacture of ethyl alcohol in certain forms of wood distillation, and for the production of power by means of gas producers, which gives five times as much heat per cord as does the ordinary method of wood burning.

Experiments have shown that it is possible to manufacture an excellent grade of unbleached chemical pulp from yellow pine. This is the kind of pulp which at present is imported in large quantities from Europe, the amount in 1910 being 374,576,000 pounds, valued at $5,831,000.

[1] See article by McGarvey Cline, written while Director Forest Products Laboratory, in the Southern Lumber Journal, Mar. 1, 1912, on "The Possible Utilization of Yellow Pine Stumpage."

Pine slabs as well as small logs and top logs can readily be converted into a high-grade chemical pulp, and if such material can be delivered to a suitably located paper mill, at the low price that seems possible in certain localities, it is practically certain that the Southern States could produce certain grades of paper in competition with the world.

PRESENT LUMBER PRICES.

The price received for loblolly pine lumber in the region covered by this report varies according as it is sold mill-run, either air-dried or green (principally to the local trade), or is kiln-dried, graded, and sold as North Carolina pine to the general lumber trade.

In the Delaware-Maryland-Virginia peninsula and on the western shore of Maryland practically the entire cut is sold locally mill-run and air-dried or green. Table 4 gives the average prices [1] received for loblolly pine lumber on the peninsula f. o. b. railroad or at factories and mills along the railroad.

TABLE 4.—*Prices of loblolly pine lumber in the Delaware-Maryland-Virginia Peninsula.*

	Per thousand.
1 inch thick, square-edge boards	$13. 50
Small-dimension stuff	12. 00
¾-inch thick board (for box factories)	11. 50
Crate flitch [2]	10. 00
Mine props [3] not sawed into lumber (in the round, and 11 to 17 inches in diameter in the middle of log)	12. 00 to 15. 00
Cull mine props [4] (less than 11 inches middle diameter)	7. 00 to 8. 75

Throughout the mainland of Virginia by far the larger part of the loblolly pine lumber output, after being kiln-dried and graded, is sold to the general lumber trade as North Carolina pine, or else is air-dried and graded as Virginia pine. Table 5 gives recent prices paid by wholesale merchants to manufacturers for the principal grades of North Carolina pine rough lumber, f. o. b. Norfolk, the main distributing center for this lumber.

TABLE 5.—*Prices of North Carolina pine f. o. b. Norfolk, Va. (basis actual sales).* [5]

Grade.	Average quarterly prices for quarter ending—						
	Dec. 31, 1912.	Sept. 30, 1912.	June 30, 1912.	Mar. 31, 1912.	Dec. 31, 1911.	Sept. 30, 1911.	June 30, 1911.
Under 12″ width:							
No. 1	$27. 52	$25. 75	$25. 25	$25. 00	$24. 25	$24. 25	$24. 50
No. 2	.....	.....	23. 00	.....	.....	.....	.....
No. 3	.....	.....	17. 25	.....	.....	.....	.....
No. 4	16. 99	15. 75	15. 25	15. 25	13. 50	12. 75	12. 50
1 and 2 bark strips	.....	.....	18. 25	.....	.....	.....	.....
Box bark strips	.....	.....	10. 50	.....	.....	.....	.....

[1] March, 1912.

[2] Logs (not suitable to cut into boards), especially small, crooked logs, are slabbed on three sides and cut into "flitch" 2″, 2½″, or 3″ in thickness, with variable widths on either face in each piece and scaled on the basis of the average width.

[3] Mine props sell at $3 a ton, green, f. o. b. railroad. It takes from 4 to 5 tons, or 8,000 to 10,000 pounds, of green mine props to cut out 1,000 board feet of 4/4 edge lumber, so that the price of $3 per ton amounts to $12 or $15 per thousand board feet.

[4] Cull mine props sell for $1.75 per ton, green, or $7 to $8.75 per thousand. The cost, figured in 1,000 board feet, of hauling green mine props amounts to about four times that of dry lumber, and for this reason props are cut only within a short haul of from 1 to 2 miles of the railroad.

[5] Selling price of wholesalers to retailers would be higher than the above prices.

COST OF LUMBER PRODUCTION.

In most of the region covered by this report the logs are cut by small portable or semiportable mills. The large mills are limited to the southeastern corner of Virginia, but even these are now securing the bulk of their logs by rail or water from North and South Carolina, as the supply in Virginia is largely cut out. In the future there will be only small mills which can be cheaply moved so as to saw up profitably isolated lots containing as little as 100,000 feet of standing timber. These, therefore, will deserve chief consideration in the management of loblolly-pine forests.

The cost of producing lumber, from the stump to the railroad or to a local market, exclusive of price paid for standing timber or stumpage, includes the following items where the milling is done by portable mills located in or near the timber: (1) Cutting and logging to the mill; (2) milling, including sawing and "sticking up;" (3) hauling lumber to the railroad or factory, including loading and unloading; (4) contractor's profit. For large mills located on the railroad there is in place of the hauling item a small charge for loading on the cars, and the cost item of logging to the mill is always considerably higher.

Cost Exclusive of Hauling.

The cost of producing loblolly pine lumber by small mills in the region, exclusive of hauling, is about as follows:

Table 6.—*Cost of lumbering (except hauling) per thousand board feet.*

	Minimum.	Average.	Maximum.
Cutting	$0.50	$0.75	$1.00
Skidding or hauling logs to mill	1.50	1.75	2.00
Sawing and "sticking up"	2.00	2.50	3.00
Contractor's profit	.50	1.00	1.50
Total (except hauling)	4.50	6.00	7.50

Hauling.

The cost of hauling is the most variable factor in the cost of lumber production by small mills, the variation being due to distance of mill from the railroad or local market, as well as to cost of team. A team of three horses (or mules) with driver can haul readily under present average road conditions in the region 2,000 feet of loblolly pine lumber a distance of 8 miles and return the same day, at an average speed of 2 miles an hour for the round trip. The cost of such a team in the region varies from $5 to $7 per day, depending largely on the season of the year. It is the custom for two such teams to work together, so that the two drivers can help each other in loading and unloading

and in case either of the teams becomes stalled. It takes about an hour to load and unload a wagon. When more than one trip a day is made, 20 cents per trip (10 cents per thousand) extra should be added for additional labor to assist in loading. Taking the above figures as a basis, the cost of hauling different distances is as follows:

TABLE 7.—*Cost of hauling lumber, including loading and unloading.*

Distance of mill from railroad or local market.	Number of trips under average conditions.	Hauling cost per M b. f.		
		Cost of team, $5 minimum.	Cost of team, $6 average.	Cost of team, $7 maximum.
16 miles	1 trip in 2 days	$5.00	$6.00	$7.00
12 miles	2 trips in 3 days	3.75	4.50	5.25
8 miles	1 trip daily	2.50	3.00	3.50
6 miles	3 trips in 2 days	1.67	2.00	2.33
4 miles	2 trips daily	1.33	1.60	1.87
2½ miles	3 trips daily	1.00	1.20	1.40
1½ miles	4 trips daily	.87	1.05	1.13
1 mile	5 trips daily	.83	1.00	1.17

TOTAL COST OF LUMBER.

Combining the average costs given in Tables 6 and 7 gives Table 8, which shows the average total cost of producing lumber at different distances from the railroad or local markets.

TABLE 8.—*Cost of producing loblolly pine lumber, per thousand board feet.*

16 miles	$12.00	4 miles	$7.60
12 miles	10.50	2 miles	7.20
8 miles	9.00	1 mile	7.00
6 miles	8.00		

The cost of producing North Carolina pine in southeastern Virginia for the general lumber market by moderate-sized mills varies much less with the distance of the timber from the railroad than in the case of small portable mills. The larger mills are located on a railroad or on water affording facilities for direct transportation to the general market, and use narrow-gauge railroads, locally called trams, for transporting logs from the woods to the mill. These mills have a usual capacity of about 15,000 feet per day, and an actual output of from 2 to 3 million feet a year. Where small portable mills can profitably be set up for a cutting of only 50,000 feet, a moderate-sized mill with tram and dry kiln requires a stand of 2 million or more feet to be logged to the mill at a single point. The cost of producing North Carolina pine in southeastern Virginia by moderate-sized mills where there is a cut of 5 million feet accessible to one set-up is given in Table 9. For larger cuts from one setting of mill and tram the cost of tramming and milling would be less.

TABLE 9.—*Cost of producing North Carolina pine lumber in southeastern Virginia.*

Item.	Tramming distance in miles.						
	1	2	4	6	8	12	16
Cutting and logging to tram, including loading [1]	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
Tramming [2]	.50	.70	1.10	1.50	1.90	2.70	3.50
Milling, including kiln-drying and loading	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Contractor's profit	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Freight [3]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	9.50	9.70	10.10	10.50	10.90	11.70	12.50

[1] Cost of logging within half mile of tram, including cutting, hauling, and loading on cars, is figured at $4 per 1,000, Doyle scale, which amounts to $3 or less mill cut.

[2] $750 per mile (15 cents per 1,000 board feet hauled) is allowed for cost of laying tram and depreciation in value of rails, the latter item being insignificant; and 5 cents per 1,000 board feet allowed for each additional mile of tram for increased cost of maintenance and operation.

[3] Cost of lumbering is figured f. o. b. Norfolk or to the nearest point on the railroad that will have an equally low freight rate to the general market. On an average, for mills in southeastern Virginia, this will add about $1 per 1,000 board feet to the cost of North Carolina pine lumber.

VALUE OF STANDING TIMBER.

The stumpage value or price which a lumber contractor can afford to pay for standing timber represents the difference between the f. o. b. railroad values for lumber and the cost of production. By subtracting from the values given in Table 4 the costs given in Table 8 we obtain the figures given in Table 10, which shows the present stumpage value of standing timber in the Delaware-Maryland-Virginia peninsula at different distances from the railroad.

TABLE 10.—*Value of standing loblolly pine per 1,000 board feet to be cut into boards and in flitch.*

Distance.	1 inch square-edged boards (ungraded).	Flitch.	Distance.	1 inch square-edged boards (ungraded).	Flitch.
16 miles	$1.50		4 miles	$5.90	$2.40
12 miles	3.00		2 miles	6.30	2.80
8 miles	4.50	$1.00	1 mile	6.50	3.00
6 miles	5.50	2.00			

This table represents pretty well the value of standing loblolly pine in most of the area under consideration. Timber of sufficient size to make first-class mine props and within 1 to 2 miles of the railroad in the Delaware-Maryland-Virginia peninsula commands slightly higher stumpage prices for props than is given above for lumber. Many cases can be found, furthermore, of $5 being paid for stumpage as far as 8 miles from the railroad, so that above values may be considered fairly conservative.

The average value, by grades, of standing loblolly pine at different distances from the railroad in the region where the timber is to be sold to the general market as North Carolina pine is shown in Table 11.

This table is based on the values given in Table 5 [1] less the cost of production as given in Table 9.

TABLE 11.—*Stumpage value of grades of standing loblolly pine to be cut into North Carolina pine lumber.*

Grade.	Distance from the railroad (miles).						
	1	2	4	6	8	12	16
	Value per 1,000 board feet.						
No. 1	$15.75	$15.55	$15.15	$14.75	$14.35	$13.55	$12.75
No. 2	13.50	13.30	12.90	12.50	12.10	11.30	10.50
No. 3	7.75	7.55	7.15	6.75	6.35	5.55	4.75
No. 4 under 10 inches	5.75	5.55	5.15	4.75	4.35	3.55	2.75
Nos. 1 and 2 bark strips	8.75	8.55	8.15	7.75	7.35	6.55	5.75
Box bark strips	1.00	.80	.40	.....	.....	.....	.....

The value of standing loblolly pine timber of different diameters at different distances from the railroad is shown in Tables 12 and 13, the former being for trees cut into inch-thick boards (ungraded) and crate flitch for local consumption, and the latter for trees manufactured into lumber for the general market in accordance with the grading specifications for North Carolina pine lumber. The former includes all trees 5 inches and over in diameter breast-high, while the latter includes only trees 7 inches and over.

TABLE 12.—*Stumpage value of loblolly pine trees of different diameters and of average height to be cut into ungraded square-edged, inch lumber and crate flitch.* [2]

Diameter breasthigh.	Average height.	Distance from the local markets (miles).						
		1	2	4	6	8	12	16
Inches.	*Feet.*							
5	37	$0.02	$0.02	$0.01	$0.01	$0.01	.....	.....
6	42	.04	.04	.03	.03	.01	.....	.....
7	47	.16	.15	.14	.13	.11	$0.07	$0.04
8	50	.20	.20	.18	.17	.14	.09	.05
9	54	.26	.25	.24	.22	.18	.12	.06
10	57	.33	.32	.30	.28	.23	.15	.08
11	60	.43	.42	.39	.36	.30	.20	.10
12	62	.57	.55	.52	.48	.40	.26	.13
13	64	.76	.74	.69	.64	.53	.35	.18
14	66	.98	.95	.89	.83	.68	.45	.23
15	68	1.23	1.19	1.12	1.04	.85	.57	.29
16	70	1.46	1.41	1.34	1.23	1.01	.67	.34
17	71	1.65	1.60	1.50	1.40	1.14	.76	.38
18	72	1.84	1.78	1.67	1.56	1.27	.85	.42
19	74	2.01	1.95	1.82	1.70	1.39	.93	.46
20	75	2.18	2.12	1.98	1.85	1.51	1.01	.50

[1] Average prices f. o. b. Norfolk, for the quarter ending June 30, 1912, were used. Prices have risen considerably since June, as shown by Table 5, so values given in Table 11 are conservative.

[2] Based on Table 39, Appendix D, showing amount of flitch and inch lumber cut from trees of different diameters, and Table 10, showing values of these grades on the stump at different distances from the market.

TABLE 13.—*Stumpage value of loblolly pine trees of different diameters, of average height, to be manufactured into North Carolina pine lumber.*[1]

Diameter, breasthigh.	Average height.	Distance from the railroad (miles).						
		1	2	4	6	8	12	16
Inches.	*Feet.*							
7	47	$0.14	$0.14	$0.13	$0.12	$0.11	$0.09	$0.07
8	50	.18	.18	.17	.15	.14	.12	.09
9	54	.26	.25	.23	.22	.20	.17	.14
10	57	.33	.33	.32	.30	.28	.25	.20
11	60	.48	.46	.44	.41	.38	.34	.28
12	62	.63	.62	.60	.56	.51	.45	.38
13	64	.88	.85	.80	.76	.71	.64	.54
14	66	1.17	1.14	1.09	1.02	.95	.84	.73
15	68	1.53	1.49	1.42	1.34	1.27	1.13	.98
16	70	1.87	1.82	1.75	1.66	1.57	1.40	1.22
17	71	2.20	2.14	2.03	1.93	1.83	1.64	1.45
18	72	2.47	2.42	2.30	2.19	2.08	1.87	1.63
19	74	2.76	2.69	2.57	2.45	2.32	2.08	1.83
20	75	3.03	2.96	2.82	2.69	2.55	2.29	2.02

[1] Based on Table 43, Appendix D, showing the amount of grades cut from trees of different diameters, and Table 11, showing value by grades of standing timber at different distances from the market.

The stumpage values per acre of even-aged fully stocked stands of loblolly pine of different ages, on different qualities of soil and at different distances from the railroad, are shown in Tables 14 and 15.

TABLE 14.—*Stumpage value per acre of even-aged, fully stocked stands of loblolly pine cut into ungraded inch boards and crate flitch.*[1]

[All trees 5 inches and over in diameter, breasthigh, included.]

Age (years).	Quality of site.	Distance from railroad (miles).						
		1	2	4	6	8	12	16
		Stumpage value per acre of ungraded boards and flitch.						
20	I	$43.10	$41.44	$38.12	$34.80	$26.50	$15.60	$7.80
	II	26.70	25.62	23.46	21.30	15.90	9.00	4.50
	III	11.55	10.99	9.87	8.75	5.95	2.70	1.35
25	I	70.95	68.53	63.69	58.85	46.75	29.70	14.85
	II	46.00	44.38	41.14	37.90	29.80	18.60	9.30
	III	20.55	19.67	17.91	16.15	11.75	6.30	3.15
30	I	98.80	95.62	89.26	82.90	67.00	43.80	21.90
	II	65.90	63.70	59.30	54.90	43.90	28.20	14.10
	III	30.25	29.05	26.65	24.25	18.25	10.50	5.25
35	I	125.95	122.01	114.13	106.25	86.55	57.30	28.65
	II	84.80	82.04	76.52	71.00	57.20	37.20	18.60
	III	42.35	40.81	37.73	34.65	26.95	16.50	8.25
40	I	154.70	149.94	140.42	130.90	107.10	71.40	35.70
	II	103.70	100.38	93.74	87.10	70.50	46.20	23.10
	III	54.80	52.92	49.16	45.40	36.00	22.80	11.40
45	I	182.65	177.03	165.75	154.55	126.45	84.30	42.15
	II	123.95	120.05	112.25	104.45	84.95	56.10	28.05
	III	69.60	67.34	62.82	58.30	47.00	30.60	15.30
50	I	211.90	205.38	192.34	179.30	146.70	97.80	48.90
	II	146.90	142.38	133.34	124.30	101.70	67.80	33.90
	III	87.10	84.42	79.06	73.70	60.30	40.20	20.10

[1] Based on Table 2, showing yield of fully stocked stands, and Table 10, showing value of loblolly pine at different distances from the railroad.

TABLE 15.—*Stumpage value per acre of even-aged, fully stocked stands of loblolly pine to be manufactured into graded North Carolina pine lumber.*[1]

[Trees 7 inches and over in diameter, breast-high.]

Age (years).	Quality of site.	Distance from railroad miles.						
		1	2	4	6	8	12	16
		Stumpage value per acre of graded North Carolina pine lumber.						
20	I	$32.83	$31.78	$29.69	$27.61	$25.71	$21.93	$18.14
	II	17.81	17.23	16.06	14.89	13.85	11.78	9.71
	III	5.16	4.98	4.60	4.26	3.95	3.32	2.69
30	I	99.50	96.57	90.72	84.87	79.46	68.65	57.84
	II	61.14	59.27	55.52	51.79	48.35	41.49	34.63
	III	22.52	21.81	20.39	18.98	17.68	15.09	12.50
40	I	175.05	170.29	160.77	151.25	142.20	124.13	106.03
	II	108.91	105.82	99.63	93.46	87.67	76.13	64.57
	III	52.66	51.14	48.09	45.05	42.22	36.59	30.95
50	I	259.91	253.38	240.34	227.30	214.66	189.37	164.05
	II	168.49	163.95	154.93	145.28	137.29	120.12	102.94
	III	97.64	94.97	89.62	84.25	79.22	69.14	59 06

[1] Based on Table 23, showing the yield by grades of fully stocked stands, and Table 11, showing value of grades at different distances from the market.

PAST AND FUTURE LUMBER VALUES.

The following tables are given to show the upward tendency in the past of two important grades of North Carolina pine lumber. They indicate that present prices will in all probability be exceeded in the future, or at least be maintained.

Table 16 gives the average wholesale prices at which North Carolina pine rough lumber, under 12 inches in width, was actually sold during 13 quarter-year periods.

TABLE 16.—*North Carolina pine prices per thousand board feet f. o. b. Norfolk.*

Period.	No. 1 edge 4/4[1] under 12-inch width.	Box edge 4/4 under 12-inch width.
October, November, December, 1909	$25.25	$12.50
January, February, March, 1910	22.00	13.00
April, May, June, 1910	24.75	12.50
July, August, September, 1910	24.00	12.50
October, November, December, 1910	24.50	12.50
January, February, March, 1911	24.75	13.00
April, May, June, 1911	24.50	12.50
July, August, September, 1911	24.25	12.75
October, November, December, 1911	24.25	13.50
January, February, March, 1912	25.00	15.25
April, May, June, 1912	25.25	15.25
July, August, September, 1912	25.75	15.75
October, November, December, 1912	27.52	16.99

[1] 4/4 refers to the thickness of the lumber. It means that it is four quarter inches or one inch in thickness.

Table 17 gives the average listed North Carolina Association prices by grades, for rough lumber under 12 inches in width, for the last 24 years. Prices f. o. b. Norfolk, per thousand board feet.

TABLE 17.—*List prices of the North Carolina Pine Association for lumber of different grades, f. o. b. Norfolk, Va.*

Year.	No. 1.	No. 2.	No. 3.	No. 4 or box.	Year.	No. 1.	No. 2.	No. 3.	No. 4 or box.
1899	$15.00	$13.00	$9.50	$7.50	1901	$20.00	$18.00	$13.25	$11.25
1890	15.00	13.00	9.50	7.50	1902	20.00	18.00	13.00	11.50
1891	15.25	13.00	9.50	7.75	1903	20.00	18.00	13.50	12.25
1892	15.75	13.25	9.50	8.25	1904	22.00	18.50	14.50	12.50
1893	15.50	13.50	9.50	8.50	1905	27.50	24.00	19.50	14.75
1894	14.50	13.00	9.50	8.50	1906	30.00	28.00	21.50	16.50
1895	13.75	12.25	9.25	8.25	1907	27.50	25.50	17.50	14.75
1896	13.75	12.00	9.00	7.75	1908	27.00	24.00	17.50	13.50
1897	13.65	11.75	9.00	7.75	1909	27.00	24.00	17.50	13.50
1898	14.60	13.00	10.00	8.25	1910	27.00	24.00	17.50	13.50
1899	18.00	16.25	12.75	11.00	1911	27.00	24.00	17.50	14.00
1900	20.00	18.00	14.00	12.00	1912	33.00	31.00	23.50	[1] 19.50

[1] 1912 figures 20 to 30 per cent higher than average sale prices. Compare with tables 5 and 16. The sudden jump in prices in 1912 was due to a revision of the Association's list prices. These list prices furnish only a slight basis for actual prices, being used to maintain and if possible to raise actual prices.

It will be noted that these list prices run from 50 cents to $1.25 higher on the No. 4 grade than the actual sale prices, and from $2 to $3 higher on the No. 1 grade. They give a good idea, however, of the upward trend of North Carolina pine lumber prices during the last 24 years. Table 18, which gives the average of the above list prices in five-year periods, emphasizes still more strongly the upward tendency of prices, especially for the lower grades.

TABLE 18.—*List prices of the North Carolina Pine Association averaged for 5-year periods, f. o. b. Norfolk per thousand board feet.*

Period.	No. 1.	No. 14 (edge box.)	Period.	No. 1.	No. 4 (edge box.)
1889–1890	$15.00	$7.50	1901–1905	$22.00	$12.50
1891–1895	15.00	8.25	1906–1910	27.70	14.35
1896–1900	16.00	9.25	1911–1912	30.00	16.75

Despite the constant rise in prices the yellow-pine lumber industry has at frequent intervals been seriously handicapped by over production of the lower grades. More recently, however, the tendency of the market has been to call for a large and steady supply of low-grade lumber.

In any event, conditions in regard to low-grade lumber are applicable more to the general lumber market than to lumber produced for local consumption. In the region under consideration, which is rapidly developing along agricultural lines and has immense opportunities for further development, the local lumber trade will become of more and more importance, especially so since the supply of standing timber is becoming more and more limited. In the future, however, wherever it is planned to grow timber for production of lumber for the general market, it will undoubtedly be very important to produce a large percentage of the upper grades.

MANAGEMENT OF LOBLOLLY PINE FORESTS.

ADVISABILITY OF MANAGEMENT.

The profits to be expected from forest management of loblolly pine are shown in Tables 19, 20, 21, 22, 23, and 24, which indicate the possible money returns and corresponding compound interest rates from properly managed stands. Tables 19, 20, and 21 give returns to be expected from fully stocked stands at different ages on Quality I, II, and III soils, where the product is to be manufactured into North Carolina pine rough lumber, cutting all trees 7 inches and over in diameter breast-high, while Tables 22, 23, and 24 give the same where the product is to be cut and sold as ungraded lumber and where all trees 5 inches and over in diameter are cut.

TABLE 19.—*Net profits per acre and corresponding compound interest rates from loblolly pine, for different initial investments, rotations, and distances from market.*

QUALITY I.—FOR TREES 7 INCHES AND OVER IN DIAMETER BREASTHIGH, CUT AND GRADED AS NORTH CAROLINA PINE LUMBER.

Rotation.	Initial investments.			Cost[2] of administration and taxes at 6 per cent compound interest.	Net profit[3] and corresponding compound interest rate[4] on total initial investment at different distances from market or shipping point.							
					¼ mile.		4 miles.		8 miles.		16 miles.	
	Land.	Formation.[1]	Total.		Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.
Years.						*Per ct.*		*Per ct.*		*Per ct.*		*Per ct.*
20	$5	$0	$5	$2.21	$30.62	10.31	$27.48	9.81	$23.50	9.09	$15.93	7.42
		3	8		27.62	7.75	24.48	7.26	20.50	6.56	12.93	4.92
		5	10		25.62	6.56	22.48	6.07	18.50	5.38	10.93	3.76
		7	12		23.62	5.59	20.48	5.11	16.50	4.42	8.93	2.82
	10	0	10	3.31	29.52	7.11	26.38	6.67	22.40	6.05	14.83	4.65
		3	13		26.52	5.72	23.38	5.28	19.40	4.67	11.83	3.29
		5	15		24.52	4.96	21.38	4.53	17.40	3.93	9.83	2.55
		7	17		22.52	4.31	19.38	3.88	15.40	3.28	7.83	1.91
30	5	0	5	4.74	94.76	10.49	85.98	10.15	74.72	9.67	53.10	8.52
		3	8		91.76	8.77	82.98	8.44	71.72	7.97	50.10	6.83
		5	10		89.76	7.97	80.98	7.64	69.72	7.17	48.10	6.04
		7	12		87.76	7.31	78.98	6.99	67.72	6.52	46.10	5.40
	10	0	10	7.12	92.38	8.06	83.60	7.74	72.34	7.28	50.72	6.20
		3	13		89.38	7.12	80.60	6.80	69.34	6.35	47.72	5.27
		5	15		87.38	6.61	78.60	6.29	67.34	5.84	45.72	4.77
		7	17		85.38	6.17	76.60	5.85	65.34	5.40	43.72	4.34
40	5	0	5	9.29	165.76	9.23	151.48	8.99	132.91	8.65	96.74	7.82
		3	8		162.76	7.95	148.48	7.72	129.91	7.38	93.74	6.56
		5	10		160.76	7.35	146.48	7.12	127.91	6.78	91.74	5.97
		7	12		158.76	6.86	144.48	6.63	125.91	6.29	89.74	5.49
	10	0	10	13.93	161.12	7.36	146.84	7.12	128.27	6.79	92.10	5.98
		3	13		158.12	6.66	143.84	6.43	125.27	6.09	89.10	5.29
		5	15		156.12	6.28	141.84	6.04	123.27	5.71	87.10	4.91
		7	17		154.12	5.94	139.84	5.71	121.27	5.38	85.10	4.58
50	5	0	5	17.42	242.49	8.12	222.92	7.94	197.24	7.68	146.63	7.06
		3	8		239.49	7.11	219.92	6.93	194.24	6.67	143.63	6.06
		5	10		237.49	6.63	217.92	6.45	192.24	6.20	141.63	5.59
		7	12		235.49	6.24	215.92	6.06	190.24	5.81	139.63	5.20
	10	0	10	26.13	233.78	6.60	214.21	6.42	188.53	6.16	137.92	5.54
		3	13		230.78	6.04	211.21	5.86	185.53	5.60	134.92	4.98
		5	15		228.78	5.74	209.21	5.56	183.53	5.30	132.92	4.68
		7	17		226.78	5.47	207.21	5.29	181.53	5.04	130.92	4.42

[1] Cost of establishing a loblolly pine stand, either by natural or artificial reproduction.

[2] Three cents per acre annually for administration (including fire protection), and 6 mills on the dollar (full valuation) annually for taxes, which is above present average tax for the region.

[3] Stumpage value as given in Table 15, less original cost of formation and total cost of administration and taxes. Where no net profit is shown, a loss is indicated.

[4] Calculated by formula $p=100\left(\sqrt[n]{\frac{S+L-A}{L+F}}-1\right)$, where p=compound interest rate, n=number of years or rotation, S=stumpage value at n years, L=cost of land, F=cost of formation, and A=cost of administration and taxes in n years at 6 per cent compound interest.

TABLE 20.—*Net profits per acre and corresponding compound interest rates from loblolly pine, for different initial investments, rotations, and distances from market.*

QUALITY II.—FOR TREES 7 INCHES AND OVER IN DIAMETER BREASTHIGH, CUT AND GRADED AS NORTH CAROLINA PINE LUMBER.

Rotation.	Initial investments.			Cost[2] of administration and taxes at 6 per cent compound interest.	Net profit[3] and corresponding compound interest rate[4] on total initial investment at different distances from market or shipping point.							
					1 mile.		4 miles.		8 miles.		16 miles.	
	Land.	Formation.[1]	Total.		Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.
Years.						*Per ct.*		*Per ct.*		*Per ct.*		*Per ct.*
20	$5	$0	$5	$2.21	$15.60	7.34	$13.85	6.86	$11.64	6.20	$7.50	4.68
		3	8		12.60	4.84	10.85	4.38	8.64	3.73	4.50	2.26
		5	10		10.60	3.68	8.85	3.22	6.64	2.58	2.50	1.12
		7	12		8.60	2.74	6.85	2.28	4.64	1.65	.50	.21
	10	0	10	3.31	14.50	4.58	12.75	4.20	10.54	3.66	6.40	2.51
		3	13		11.50	3.22	9.75	2.84	7.54	2.31	3.40	1.17
		5	15		9.50	2.48	7.75	2.10	5.54	1.58	1.40	.45
		7	17		7.50	1.84	5.75	1.47	3.54	.95	-------	-------
30	5	0	5	4.74	56.40	8.72	50.78	8.37	43.61	7.88	29.89	6.69
		3	8		53.40	7.03	47.78	6.69	40.61	6.20	26.89	5.03
		5	10		51.40	6.24	45.78	5.90	38.61	5.41	24.89	4.25
		7	12		49.40	5.59	43.78	5.25	36.61	4.77	22.89	3.62
	10	0	10	7.12	54.02	6.38	48.40	6.06	41.23	5.60	27.51	4.50
		3	13		51.02	5.46	45.40	5.14	38.23	4.68	24.51	3.59
		5	15		49.02	4.96	43.40	4.63	36.23	4.18	22.51	3.10
		7	17		47.02	4.52	41.40	4.20	34.23	3.75	20.51	2.67
40	5	0	5	9.29	99.62	7.90	90.34	7.65	78.38	7.29	55.28	6.42
		3	8		96.62	6.64	87.34	6.39	75.38	6.03	52.28	5.18
		5	10		94.62	6.04	85.34	5.80	73.38	5.45	50.28	4.59
		7	12		92.62	5.56	83.34	5.32	71.38	4.96	48.28	4.19
	10	0	10	13.93	94.98	6.05	85.70	5.81	73.74	5.46	50.64	4.61
		3	13		91.98	5.36	82.70	5.12	70.74	4.77	47.64	3.92
		5	15		89.98	4.98	80.70	4.74	68.74	4.39	45.64	3.55
		7	17		87.98	4.66	78.70	4.41	66.74	4.07	43.64	3.23
50	5	0	5	17.42	151.07	7.13	137.51	6.93	119.87	6.65	85.52	5.96
		3	8		148.07	6.12	134.51	5.93	116.87	5.65	82.52	4.97
		5	10		146.07	5.65	132.51	5.46	114.87	5.18	80.52	4.50
		7	12		144.07	5.26	130.51	5.07	112.87	4.80	78.52	4.12
	10	0	10	26.13	142.36	5.60	128.80	5.40	111.16	5.12	76.81	4.42
		3	13		139.36	5.05	125.80	4.85	108.16	4.56	73.81	3.87
		5	15		137.36	4.75	123.80	4.55	106.16	4.27	71.81	3.57
		7	17		135.36	4.48	121.80	4.29	104.16	4.01	69.81	3.31

[1] Cost of establishing a loblolly pine stand, either by natural or artificial reproduction.

[2] Three cents per acre annually for administration (including fire protection), and 6 mills on the dollar (full valuation) annually for taxes, which is above present average tax for the region.

[3] Stumpage value as given in Table 15, less original cost of formation and total cost of administration and taxes. Where no net profit is shown, a loss is indicated.

[4] Calculated by formula $p=100\left(\sqrt[n]{\frac{S+L-A}{L+F}}-1\right)$, where p=compound interest rate, n=number of years or rotation, S=stumpage value at n years, L=cost of land, F=cost of formation, and A=cost of administration and taxes in n years at 6 per cent compound interest.

TABLE 21.—*Net profits per acre and corresponding compound interest rates from loblolly pine, for different initial investments, rotations, and distances from market.*

QUALITY III.—FOR TREES 7 INCHES AND OVER IN DIAMETER BREAST HIGH, CUT AND GRADED AS NORTH CAROLINA PINE LUMBER.

Rotation.	Initial investment.			Cost[2] of administration and taxes at 6 per cent compound interest.	Net profit[3] and corresponding compound interest rate[4] on total initial investment at different distances from market or shipping point.							
					1 mile.		4 miles.		8 miles.		16 miles.	
	Land.	Formation.[1]	Total.		Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.
Years.						*Per ct.*		*Per ct.*		*Per ct.*		*Per ct.*
20	$5	$0	$5	$2.21	$2.95	2.35	$2.39	1.97	$1.74	1.50	$0.48	0.46
		3	8									
		5	10									
		7	12									
	10	0	10	3.31	1.85	.85	1.29	.61	.64	.31		
		3	13									
		5	15									
		7	17									
30	5	0	5	4.74	17.78	5.18	15.65	4.84	12.94	4.35	7.76	3.17
		3	8		14.78	3.56	12.65	3.21	9.94	2.73	4.76	1.57
		5	10		12.78	2.78	10.65	2.45	7.94	1.97	2.76	.82
		7	12		10.78	2.16	8.65	1.83	5.94	1.35	.76	.20
	10	0	10	7.12	15.40	3.16	13.27	2.86	10.56	2.43	5.38	1.44
		3	13		12.40	2.26	10.27	1.96	7.56	1.54	2.38	.56
		5	15		10.40	1.77	8.27	1.47	5.56	1.06	.38	.08
		7	17		8.40	1.35	6.27	1.05	3.56	.63		
40	5	0	5	9.29	43.37	5.84	38.80	5.58	32.93	5.20	21.66	4.27
		3	8		40.37	4.60	35.80	4.34	29.93	3.97	18.66	3.06
		5	10		38.37	4.02	33.80	3.76	27.93	3.39	16.66	2.48
		7	12		36.37	3.55	31.80	3.29	25.93	2.92	14.66	2.02
	10	0	10	13.93	38.73	4.04	34.16	3.78	28.29	3.41	17.02	2.52
		3	13		35.73	3.36	31.16	3.10	25.29	2.74	14.02	1.85
		5	15		33.73	2.99	29.16	2.74	23.29	2.37	12.02	1.48
		7	17		31.73	2.67	27.16	2.42	21.29	2.05	10.02	1.16
50	5	0	5	17.42	80.22	5.83	72.20	5.63	61.80	5.32	41.64	4.57
		3	8		77.22	4.84	69.20	4.64	58.80	4.34	38.64	3.59
		5	10		75.22	4.38	67.20	4.17	56.80	3.87	36.64	3.13
		7	12		73.22	4.00	65.20	3.79	54.80	3.49	34.64	2.75
	10	0	10	26.13	71.51	4.29	63.49	4.07	53.09	3.75	32.93	2.96
		3	13		68.51	3.74	60.49	3.53	50.09	3.21	29.93	2.42
		5	15		66.51	3.44	58.49	3.23	48.09	2.91	27.93	2.12
		7	17		64.51	3.18	56.49	2.97	46.09	2.66	25.93	1.87

[1] Cost of establishing a loblolly pine stand, either by natural or artificial reproduction.

[2] Three cents per acre annually for administration (including fire protection), and 6 mills on the dollar (full valuation) annually for taxes, which is above present average tax for the region.

[3] Stumpage value as given in Table 15, less original cost of formation and total cost of administration and taxes. Where no net profit is shown, a loss is indicated.

[4] Calculated by formula $p=100\left(\sqrt[n]{\frac{S+L-A}{L+F}}-1\right)$, where p=compound interest rate, n=number of years or rotation, S=stumpage value at n years, L=cost of land, F=cost of formation, and A=cost of administration and taxes in n years at 6 per cent compound interest.

TABLE 22.—*Net profits per acre and corresponding compound interest rates from loblolly pine, for different initial investments, rotations, and distances from market.*

QUALITY I.—FOR TREES 5 INCHES AND OVER IN DIAMETER BREASTHIGH, LUMBER CUT AND SOLD UNGRADED.

Rotation.	Initial investment.			Cost[2] of administration and taxes at 6 per cent compound interest.	Net profit[3] and corresponding compound interest rate[4] on total initial investment at different distances from market or shipping point.							
					1 mile.		4 miles.		8 miles.		16 miles.	
	Land.	Formation.[1]	Total.		Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.
Years.						*Per ct.*		*Per ct.*		*Per ct.*		*Per ct.*
20	$5	$0	$5	$2.21	$40.89	11.72	$35.91	11.08	$24.29	9.24	$5.59	3.82
		3	8		37.89	9.13	32.91	8.50	21.29	6.70	2.59	1.41
		5	10		35.89	7.92	30.91	7.30	19.29	5.52	.59	.29
		7	12		33.89	6.94	28.91	6.32	17.29	4.56	.....	.....
	10	0	10	3.31	39.79	8.36	34.81	7.79	23.19	6.18	4.49	1.87
		3	13		36.79	6.94	31.81	6.38	20.19	4.80	1.49	.54
		5	15		34.79	6.18	29.81	5.62	18.19	4.05	.....	.....
		7	17		32.79	5.52	27.81	4.97	16.19	3.40	.....	.....
30	5	0	5	4.74	94.06	10.47	84.52	10.09	62.26	9.05	17.16	5.09
		3	8		91.06	8.74	81.52	8.38	59.26	7.36	14.16	3.45
		5	10		89.06	7.94	79.52	7.58	57.26	6.56	12.16	2.69
		7	12		87.06	7.29	77.52	6.93	55.26	5.91	10.16	2.07
	10	0	10	7.12	91.68	8.04	82.14	7.68	59.88	6.70	14.78	3.07
		3	13		88.68	7.10	79.14	6.75	56.88	5.77	11.78	2.17
		5	15		86.68	6.59	77.14	6.24	54.88	5.26	9.78	1.69
		7	17		84.68	6.14	75.14	5.79	52.88	4.83	7.78	1.26
40	5	0	5	9.29	145.41	8.88	131.13	8.61	97.81	7.85	26.41	4.70
		3	8		142.41	7.61	128.13	7.34	94.81	6.59	23.41	3.48
		5	10		140.41	7.01	126.13	6.75	92.81	6.00	21.41	2.90
		7	12		138.41	6.52	124.13	6.26	90.81	5.52	19.41	2.44
	10	0	10	13.93	140.77	7.02	126.49	6.75	93.17	6.01	21.77	2.93
		3	13		137.77	6.32	123.49	6.05	90.17	5.31	18.77	2.26
		5	15		135.77	5.94	121.49	5.68	88.17	4.94	16.77	1.89
		7	17		133.77	5.61	119.49	5.35	86.17	4.61	14.77	1.58
50	5	0	5	17.42	194.48	7.65	174.92	7.42	129.28	6.80	31.48	4.06
		3	8		191.48	6.64	171.92	6.42	126.28	5.80	28.48	3.08
		5	10		189.48	6.17	169.92	5.95	124.28	5.33	26.48	2.62
		7	12		187.48	5.78	167.92	5.56	122.28	4.95	24.48	2.25
	10	0	10	26.13	185.77	6.13	166.21	5.91	120.57	5.27	22.77	2.40
		3	13		182.77	5.57	163.21	5.35	117.57	4.72	19.77	1.87
		5	15		180.77	5.27	161.21	5.05	115.57	4.42	17.77	1.57
		7	17		178.77	5.01	159.21	4.79	113.57	4.16	15.77	1.32

[1] Cost of establishing a loblolly pine stand, either by natural or artificial reproduction.

[2] Three cents per acre annually for administration (including fire protection) and 6 mills on the dollar (full valuation) annually for taxes, which is above present average tax for the region.

[3] Stumpage value as given in Table 14, less original cost of formation and total cost of administration and taxes. Where no net profit is shown, a loss is indicated.

[4] Calculated by formula $p=100\left(\sqrt[n]{\frac{S+L-A}{L+F}}-1\right)$, where p = compound interest rate, n=number of years or rotation, S=stumpage value at n years, L=cost of land, F=cost of formation, and A=cost of administration and taxes in n years at 6 per cent compound interest.

TABLE 23.—*Net profits per acre and corresponding compound interest rates from loblolly pine, for different initial investments, rotations, and distances from market.*

QUALITY II.—FOR TREES 5 INCHES AND OVER IN DIAMETER BREASTHIGH, LUMBER CUT AND SOLD UNGRADED.

Rotation.	Initial investment.			Cost[2] of administration and taxes at 6 per cent compound interest.	Net profit[3] and corresponding compound interest rate[4] on total initial investment at different distances from market or shipping point.							
					1 mile.		4 miles.		8 miles.		16 miles.	
	Land.	Formation.[1]	Total.		Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.
Years.						*Per ct.*		*Per ct.*		*Per ct.*		*Per ct.*
20	$5	$0	$5	$2.21	$24.49	9.28	$21.25	8.64	$13.69	6.82	$2.29	1.90
		3	8		21.49	6.74	18.25	6.12	10.69	4.33	.....	.....
		5	10		19.49	5.56	16.25	4.94	8.69	3.18	.....	.....
		7	12		17.49	4.60	14.25	3.99	6.69	2.24	.....	.....
	10	0	10	3.31	23.39	6.21	20.15	5.67	12.59	4.16	1.19	.56
		3	13		20.39	4.83	17.15	4.30	9.59	2.80	.....	.....
		5	15		18.39	4.08	15.15	3.55	7.59	2.07	.....	.....
		7	17		16.39	3.43	13.15	2.91	5.59	1.43	.....	.....
30	5	0	5	4.74	61.16	8.99	54.56	8.61	39.16	7.53	9.36	3.58
		3	8		58.16	7.30	51.56	6.92	36.16	5.86	6.36	1.97
		5	10		56.16	6.50	49.56	6.13	34.16	5.08	4.36	1.21
		7	12		54.16	5.85	47.56	5.49	32.16	4.44	2.36	.60
	10	0	10	7.12	58.78	6.64	52.18	6.28	36.78	5.28	6.98	1.78
		3	13		55.78	5.71	49.18	5.36	33.78	4.36	3.98	.89
		5	15		53.78	5.21	47.18	4.85	31.78	3.86	1.98	.41
		7	17		51.78	4.77	45.18	4.42	29.78	3.43	.....	.....
40	5	0	5	9.29	94.41	7.76	84.45	7.48	61.21	6.67	13.81	3.37
		3	8		91.41	6.50	81.45	6.22	58.21	5.43	10.81	2.16
		5	10		89.41	5.91	79.45	5.63	56.21	4.84	8.81	1.59
		7	12		87.41	5.43	77.45	5.15	54.21	4.36	6.81	1.13
	10	0	10	13.93	89.77	5.92	79.81	5.64	56.57	4.85	9.17	1.64
		3	13		86.77	5.23	76.81	4.95	53.57	4.17	6.17	.98
		5	15		84.77	4.85	74.81	4.58	51.57	3.80	4.17	.61
		7	17		82.77	4.52	72 81	4.25	49.57	3.47	2.17	.30
50	5	0	5	17.42	129.48	6.81	115.92	6.58	84.28	5.93	16.48	2.96
		3	8		126.48	5.81	112.92	5.58	81.28	4.94	13.48	2.00
		5	10		124.48	5.34	110.92	5.11	79.28	4.48	11.48	1.54
		7	12		122.48	4.95	108.92	4.73	77.28	4.10	9.48	1.17
	10	0	10	26.13	120.77	5.28	107.21	5.05	75.57	4.39	7.77	1.17
		3	13		117.77	4.72	104.21	4.50	72.57	4.08	4.77	.63
		5	15		115.77	4.43	102.21	4.20	70.57	3.54	2.77	.34
		7	17		113.77	4.16	100.21	3.94	68.57	3.29	.77	.09

[1] Cost of establishing a loblolly pine stand, either by natural or artificial reproduction.

[2] Three cents per acre annually for administration (including fire protection), and 6 mills on the dollar (full valuation) annually for taxes, which is above present average tax for the region.

[3] Stumpage value as given in Table 14, less original cost of formation and total cost of administration and taxes. Where no net profit is shown, a loss is indicated.

[4] Calculated by formula $p=100\left(\sqrt[n]{\frac{S+L-A}{L+F}}-1\right)$, where p= compound interest rate, n=number of years or rotation, S=stumpage value at n years, L=cost of land, F=cost of formation, and A=cost of administration and taxes in n years at 6 per cent compound interest.

TABLE 24.—*Net profits per acre and corresponding compound interest rates from loblolly pine, for different initial investments, rotations, and distances from market.*

QUALITY III.—FOR TREES 5 INCHES AND OVER IN DIAMETER BREASTHIGH, LUMBER CUT AND SOLD UNGRADED.

Rotation.	Initial investment.			Cost[2] of administration and taxes at 6 per cent compound interest.	Net profit[3] and corresponding compound interest rate[4] on total initial investment at different distances from market or shipping point.							
					1 mile.		4 miles.		8 miles.		16 miles.	
	Land.	Formation.[1]	Total.		Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.	Net profit.	Interest rate.
Years.						*Per ct.*		*Per ct.*		*Per ct.*		*Per ct.*
20	$5	$0	$5	$2.21	$9.34	5.41	$7.66	4.75	$3.74	2.83	.....	.....
		3	8		6.34	2.96	4.66	2.32	.74	.45	.....	.....
		5	10		4.34	1.82	2.66	1.19	.....	.....	.....	.....
		7	12		2.34	.90	.66	.27	.....	.....	.....	.....
	10	0	10	3.31	8.24	3.05	6.56	2.55	2.64	1.18	.....	.....
		3	13		5.24	1.71	3.56	1.22	.....	.....	.....	.....
		5	15		3.24	.98	1.56	.50	.....	.....	.....	.....
		7	17		1.24	.35	.....	.....	.....	.....	.....	.....
30	5	0	5	4.74	25.51	6.22	21.91	5.77	13.51	4.46	$0.51	0.32
		3	8		22.51	4.56	18.91	4.13	10.51	2.84	.....	.....
		5	10		20.51	3.79	16.91	3.35	8.51	2.07	.....	.....
		7	12		18.51	3.16	14.91	2.73	6.51	1.46	.....	.....
	10	0	10	7.12	23.13	4.07	19.53	3.68	11.13	2.53	.....	.....
		3	13		20.13	3.17	16.53	2.77	8.13	1.63	.....	.....
		5	15		18.13	2.68	14.53	2.28	6.13	1.15	.....	.....
		7	17		16.13	2.25	12.53	1.86	4.13	.73	.....	.....
40	5	0	5	9.29	45.51	5.95	39.87	5.64	26.71	4.73	2.11	.88
		3	8		42.51	4.71	36.87	4.41	23.71	3.50	.....	.....
		5	10		40.51	4.13	34.87	3.82	21.71	2.93	.....	.....
		7	12		38.51	3.66	32.87	3.35	19.71	2.46	.....	.....
	10	0	10	13.93	40.87	4.15	35.23	3.84	22.07	2.96	.....	.....
		3	13		37.87	3.47	32.23	3.17	19.07	2.28	.....	.....
		5	15		35.87	3.10	30.23	2.80	17.07	1.92	.....	.....
		7	17		33.87	2.78	28.23	2.48	15.07	1.60	.....	.....
50	5	0	5	17.42	69.68	5.56	61.64	5.32	42.88	4.62	2.68	.86
		3	8		66.68	4.57	58.64	4.33	39.88	3.64	.....	.....
		5	10		64.68	4.10	56.64	3.87	37.88	3.18	.....	.....
		7	12		62.68	3.72	54.64	3.49	35.88	2.81	.....	.....
	10	0	10	26.13	60.97	4.00	52.93	3.75	34.17	3.02	.....	.....
		3	13		57.97	3.45	49.93	3.20	31.17	2.48	.....	.....
		5	15		55.97	3.16	47.93	2.91	29.17	2.18	.....	.....
		7	17		53.97	2.90	45.93	2.65	27.17	1.93	.....	.....

[1] Cost of establishing a loblolly pine stand, either by natural or artificial reproduction.

[2] Three cents per acre annually for administration (including fire protection), and 6 mills on the dollar (full valuation) annually for taxes, which is above present average tax for the region.

[3] Stumpage value as given in Table 14, less original cost of formation and total cost of administration and taxes. Where no net profit is shown, a loss is indicated.

[4] Calculated by formula $p=100\left(\sqrt[n]{\frac{S+L-A}{L+F}}-1\right)$, where p= compound interest rate, n=number of years or rotation, S=stumpage value at n years, L=cost of land, F=cost of formation, and A=cost of administration and taxes in n years at 6 per cent compound interest.

The preceding tables indicate under what conditions of quality of soil, cost of land, cost of establishing crop, and distance from market forest management of loblolly pine will be profitable or advisable as a business proposition. For instance, Table 22 indicates that on 1 acre of Quality I soil, 1 mile from the railroad, where there is no cost for establishing a crop of loblolly pine, it will be possible to realize 10.47 per cent compound interest in 30 years on an initial invest-

ment of $5 for the land. If the land costs $10 there would be 8.04 per cent compound interest realized on the initial investment. These represent the most favorable conditions. Under similar conditions on Quality III land (see Table 24), on the other hand, in 30 years there will be a compound interest of only 6.22 per cent on $5 land and of 4.07 per cent on $10 land; while at 8 miles from the railroad under similar conditions the compound interest rate possible to realize would be 4.46 and 2.53 per cent, respectively, on $5 and $10 land.

Loblolly pine occurs almost entirely on land that is potentially agricultural. This includes large areas of poorly drained land which at considerable expense can be converted into good agricultural sites, and land formerly under cultivation but worn out and abandoned. For several generations it will probably pay best to continue to grow crops of timber, at comparatively little expense, on large areas of this land, and to practice intensive agriculture, requiring large outlays of money, on limited areas best adapted to crops. A properly managed woodlot will always be a necessity to the well-equipped farm, even if the only land available for this purpose is potentially agricultural.

In the management of forest types in which loblolly pine occurs it is generally advisable to favor it in the reproduction of a new stand to the exclusion of most of the species associated with it. It is preferable to other pines (shortleaf, pitch, and scrub) because its growth is more rapid, it produces cleaner timber and more seed, and on moist to wet soils, or on light dry soils with an open seed bed, it reproduces better. It is preferable to reproduce to pine rather than to hardwoods, with the exception of yellow poplar, because pine will reach maturity and command a good stumpage price at an earlier age, especially on the poorer soils. On heavy and dry upland soils, where loblolly is comparatively scarce, it is best to favor shortleaf pine, as it is better adapted than loblolly to such sites. By using the method for securing loblolly pine reproduction described in this bulletin it will be possible to secure pure stands of the species, or at least make it the preponderating species in a future stand. A limited admixture of other species of pine and hardwoods of the same age will never handicap the rapid-growing loblolly, and it will not usually be advisable to go to any considerable expense in order to exclude them entirely.

NORMAL STANDS AND ROTATION.

In forest management of loblolly pine the aim should be to secure (preferably by natural reproduction, which is less expensive) pure, fully-stocked (uniformly dense), and even-aged stands of the species. These are technically known as normal stands, and produce the

largest yield of timber per acre on a short rotation, and give the best chance of development to the trees composing them. Cuttings can best be regulated in such stands, both reproduction cuttings in mature and improvement thinnings in immature stands. Moreover, conditions for the germination of seed and the growth of seedlings are much better following the cutting of a densely stocked than of an openly stocked stand. Only a small percentage of unmanaged loblolly stands are fully stocked, or normal. It will usually be possible, however, by leaving several good loblolly seed trees per acre, evenly distributed, to secure sufficient natural reproduction on a cut-over area to form a fully stocked stand of second growth. On areas with an insufficient number of loblolly seed trees, or with seed trees unevenly distributed, sowing or planting to supplement natural reproduction will be necessary if it is wished to get a normal stand.

One of the first steps in forest management is to decide the rotation, or age at which the forest is to be considered mature, and at which to cut and reproduce it. On a rotation of from 20 to 30 years for loblolly pine it is only possible to produce round-edge box boards, crating stuff, and lumber of the lowest grades and of small value. On a rotation of from 35 to 45 years considerable medium-grade lumber can be produced which will command a fair stumpage price. But to produce any very considerable percentage of lumber of the best grades a rotation of from 50 to 100 years is necessary. The rotation to obtain the highest rate of interest on the original investment in a loblolly-pine forest appears from Tables 19, 20, 21, 22, 23, and 24 to be, for the most part, from 30 to 50 years—longer on Quality III and shorter on Quality I soils. Although these tables go only to 50 years, it is safe to say that a longer rotation, even after allowing for increase in the board feet yield and stumpage value would not show such a high rate of interest on the money invested There is also to be considered the danger from fire, insects, and disease, which is against a long rotation. A rotation of from 35 to 45 years is also the best silviculturally, because at this age loblolly-pine stands can be most easily reproduced. This is especially true where loblolly occurs as a temporary forest type, which, if left to the course of nature, would gradually revert to the original type.

The time for cutting any particular stand, however, should not necessarily be made to coincide with the rotation which has been previously decided upon as the best, but should also be influenced by the condition of the lumber market and the occurrence of seed years. In some cases the market may make it advisable to let the stand grow for a much longer period than the rotation calls for, in order to produce more lumber of the higher grades, or a combination of a good seed year and a good market for low-grade stuff may warrant cutting on a shorter rotation.

FIRE PROTECTION.

Management of loblolly-pine land to secure successive crops of timber is not advisable unless there is a reasonable certainty that forest fires can and will be controlled or kept out entirely. Adequate protection from fire, therefore, must be provided before it becomes worth while to incur any expense connected with forest management. Fire kills the reproduction, thins out existing stands, and lessens the rate of growth of the remaining trees by impairing their vitality and by reducing the productive capacity of the soil. The thinning is done by (1) killing trees outright; (2) weakening trees so that they succumb to attacks of insects or fungi; (3) burning the trunks so that the trees are broken off or thrown by the wind.

In loblolly pine it is best to keep fire out entirely. The only exception to this rule is in burning brush litter and undergrowth after lumbering to lessen the possibility of future damage from fire and to improve conditions for reproduction. Such burnings, however, should not be carried out unless it is certain that the fire can and will be limited to the area it is wished to stock.

It is a comparatively simple and easy matter to keep fire out of small blocks of timber, up to 500 acres in extent, when these are adjacent to farms or bounded by roads, cultivated fields, streams, and other barriers. The owner should be careful, however, not to allow his woods to catch from his own brush fires. He should also post his land with trespass and fire notices, keep a watch for fires continually during dry periods, and extinguish as soon as possible any which may start. The larger the area the more difficult it is to keep fire out.

For large areas the principal means of fire protection include: (1) Piling and burning of slash left after lumbering, which will also often assist reproduction; (2) development of roads, trails, and fire lines; (3) organization of a patrol and fire-fighting force, with proper equipment for fighting fires; (4) use of spark arresters on locomotives and donkey engines used in logging; (5) posting of timber-trespass and fire-warning notices and vigorous application of State fire laws, where possible, against setting of forest fires; (6) cooperative fire-protective agreements or understandings with adjacent landowners.

For detailed discussion of means and methods to employ where it is aimed to exclude all fire from the forest, and methods of fighting fire, the reader is referred to Bulletin 82 of the Forest Service, "Protection of Forests from Fire," by Henry S. Graves, Forester.

REFORESTATION BY NATURAL REPRODUCTION.

To secure natural reproduction of loblolly pine it is necessary to cut the mature stand in such a way that seed will be disseminated evenly over the bed. The subject will be discussed under the general headings of (1) methods of cutting and (2) work following cutting.

Methods of Cutting.

There are three general methods of cutting loblolly-pine forests to provide for the proper seeding of the area cut: (1) Clean cutting except for scattered individuals or groups of loblolly-pine seed trees; (2) clean cutting in strips or patches; (3) successive thinning method. The two last methods are adapted chiefly to pure or nearly pure stands of loblolly, while the first is suitable to all types and mixtures in which the species occurs.

SCATTERED SEED TREES AND SCATTERED GROUPS.

The scattered seed-tree method consists in clean cutting everything except from 4 to 10 loblolly pine seed trees per acre, left evenly distributed over the area to be reproduced. This is the simplest method and the one usually to be recommended, as it is adaptable to both pure stands and to loblolly in mixture with other species. The cutting should preferably be made when it is seen that there will be a good seed year. The number of seed trees which should be left varies with their height; if over 70 feet tall, from 4 to 7 trees per acre will be sufficient; if under 70 feet tall a larger number will be necessary. Tress which will produce the most seed should be left, i. e., trees with the largest crowns, which are also the most windfirm. Whenever there is much danger from windfall it will be best to leave scattered groups of from 3 to 9 trees. Seed trees or groups should be left to grow for another rotation, or taken out when an improvement thinning is made in the new stand. In case of mixed stands it is important to cut clean all trees of other species and to leave only loblolly seed trees.

CLEAN CUTTING IN STRIPS AND PATCHES.

These methods consist in clean cutting in strips from 100 to 150 feet wide, or clean cutting patches from 100 to 300 feet across, to be seeded from the adjacent or surrounding forest which remains intact until the area is reproduced. This method is best adapted to pure or nearly pure stands, and in any case a large proportion of the dominant trees along the edge of the adjacent uncut stand should be loblolly pine. Especial care should be taken to leave the forest intact on the side from which the prevailing fall and winter winds blow, in order to insure dissemination of the seed over the area cut. The cutting should preferably be made when it is seen that there will be a good seed year. The width of the strips should not exceed twice the height of the trees in the adjacent uncut forest, while the width of clean-cut patches can be somewhat greater.

Not over two-thirds of the area of the forest should be contained in the strips or patches cut, and preferably not more than half; in the

latter case the intact areas between the strips or patches would be equal in size to the strips or patches which are clean cut.

These methods of cutting can sometimes be advantageously used in conjunction with the scattered seed-tree method. When it is wished to cut in wider strips or larger patches than can be adequately seeded from the adjacent woods, reproduction on remote parts can be provided for by leaving scattered seed trees or groups of trees.

SUCCESSIVE THINNINGS.

This consists in removing the mature stand in two or three cuttings. It is adapted primarily to fully stocked stands of practically pure loblolly pine. Under this method the reproduction takes place more or less under the shelter of the old trees left. It can best be used on moist or wet situations, where loblolly-pine seedlings are comparatively tolerant of shade. The first cutting, so called, which may often be omitted, consists in a heavy thinning to give the crowns and roots of the trees left more growing space, thus causing them to produce more seed. Overtopped and small-crowned loblolly trees should be removed in this cutting, but the thinning should not be so heavy as to seriously interrupt the crown cover and cause large openings in the leaf canopy, which would result in the luxuriant growth of weeds and underbrush. Trees of other species, if any occur, should all be removed at this cutting. The second cutting should be made when it is seen that there is a good seed year at hand. The largest crowned trees should be left, since these produce the most seed. At this cutting about one-half the volume of the stand should be removed. The third cutting should preferably be made as soon as possible after adequate reproduction has taken place, which should be accomplished within 1 to 5 years. The younger and smaller the seedlings the less will be the damage done to them in removing the old trees. Where it is wished to take advantage of the increased growth of trees left after cutting, or where the market conditions warrant, the periods between the first and second and the second and third cuts might be prolonged to 5 or 10 years, though this will usually be disadvantageous to the reproduction.

ORDINARY METHODS OF CUTTING.

The necessity of properly planned systematic cutting according to one of the methods just described can not too strongly be emphasized whenever it is wished to provide for adequate seed production. Under ordinary methods of lumbering it is purely a matter of chance whether there will be a sufficient number of properly distributed seed trees left after cutting. Of the ordinary methods the most favorable to reproduction is the diameter-limit method, but even this is a makeshift in providing for a future stand, and only under exceptional conditions can it be relied upon to furnish adequate seed production.

Under this method the stand is cut to a rough diameter limit, either because it does not actually pay to cut trees below that limit or because it is wished to leave trees to form the basis for a second cut 10 to 20 years later.

If, in pure well-stocked stands, a large number of trees remain after lumbering by the diameter-limit method, excellent results will often be had both in the growth of trees left and in the seeding of a new stand, the cutting, in its effects, amounting to a modified form of the method of successive thinnings. The chief drawback is that the small-crowned overtopped trees, such as would be left under this method, require a number of years to recover from suppression before producing much seed; and, furthermore, a large proportion of them usually die or are windthrown or broken within a few years after lumbering, especially on dry and exposed situations. It sometimes happens, however, as shown in Table 25, that the area cut under this method is immediately seeded up from seed produced by the large-crowned trees removed at the cutting, or from seed trees left in the vicinity of the area cut. Table 25 is a summary of the results of cutting a half-acre plot in a 35-year-old fully stocked stand of loblolly pine on fresh, sandy soil, to a diameter limit of 12 inches breasthigh in the winter of 1904. The stand was measured in 1906, and remeasured 4½ years later. It indicates what sometimes happens, under favorable conditions, in cutting by the ordinary diameter-limit method. (See Plate III.)

TABLE 25.—*Effect of a diameter-limit cutting on a half acre of even-aged, fully stocked loblolly pine 35 years old.*

TREES REMOVED, TREES DYING, AND GROWTH OF TREES REMAINING.

	Removed, 1904.	Remaining.		Died, 1906–1910.	Increase (+) or decrease (−) in 4½ years.
		1906	1910		
					Per cent.
Number of trees	65	53	44	9	−17
Average diameter breasthigh	13 (12.8)	8.4	9.1	7.9	+ 7.7
Average height	70	60	60.3	60	+ .05
Volume (without bark) cubic feet	1,638	493	475	69	+ 3.7
Volume (mill scale) board feet	8,450	1,900	2,400	270	+26.3

AMOUNT AND GROWTH OF LOBLOLLY-PINE REPRODUCTION ON THE HALF ACRE.

Size.	Number.	
	1906	1910
0 to 2 feet in height	720	97
2 to 4 feet in height	101	125
4 to 6 feet in height	32	203
1 inch in diameter breasthigh	8	214
2 inches in diameter breasthigh	.....	62
3 inches in diameter breasthigh	.....	5

A 35-Year-Old Fully Stocked Stand of Loblolly Pine Cut to a Diameter Limit of 12 Inches.

[Picture, taken 2 years after lumbering, shows adequate reproduction for a new stand to follow removal of remaining trees. Yield of this stand and size and amount of reproduction given in Table 25.]

A WELL-MANAGED 23-YEAR-OLD STAND OF LOBLOLLY PINE ON QUALITY I SOIL. THINNED 5 YEARS BEFORE.

[Present yield of trees 7 inches and over in diameter breast high 10,000 board feet per acre if scaled mill cut. Since the trees are small the stand if scaled by the Doyle rule would give only 3,000 board feet per acre and by the Scribner rule 7,200 feet. Numbers painted on trees are for the purpose of identifying them in future remeasurements to determine effect of thinning.]

Work Following Cutting.

The work following cutting consists in preparing the area for the reception of the seed. Frequently no work at all will be necessary.

The work which may have to be done to insure reproduction includes: (1) Brush disposal, which also serves as a fire protective measure and lessens danger from insect infestations; (2) disturbance or destruction of the forest floor, including the leaf litter and undecomposed humus; (3) destruction of ground cover and underbrush including hardwood saplings; (4) cutting of worthless trees still standing, which, preferably, should have been removed at the time of the main cutting. The amount of work to be done varies with the character of the site, whether wet or dry; with the condition of the forest floor; and with the amount and character of the ground cover and underbrush.

On moist to wet sites no work at all is usually necessary, except where there is considerable underbrush or worthless trees which it is best to cut out. The growth of loblolly-pine seedlings on such sites is hindered little or not at all by the forest floor, ground cover, and brush left after lumbering. A fire, however, to destroy all undergrowth and brush, is rather beneficial than otherwise on such sites.

On fresh to dry sites destruction of the forest floor, ground cover, and brush is advisable and often necessary to insure reproduction. The best method is to burn it. Disturbance of the forest floor during logging operations will also improve conditions for reproduction. In burning, care should be taken not to damage trees left for seed or woods adjacent to the area cut.

The time for preparing the seedbed should be governed by the occurrence of adequate seed production, preferably at the same time as the cutting if the two coincide; otherwise not until there is a good seed year.

Where the ground is in satisfactory condition for the reproduction of the seed and there are sufficient seed trees, adequate reproduction can be expected by the end of the first or second season after a good seed year.

The cost of these rough methods of preparing the ground for the reception of the seed should in no case exceed $3 per acre, and is uniformly cheaper than reforesting artificially.

REFORESTING BY ARTIFICIAL REPRODUCTION.

Where natural reproduction fails it is always possible to secure fully-stocked stands of loblolly pine by resorting to artificial reproduction. This can be done more easily and at less expense for this species than for most if not for any other species of pines in the eastern United States.

Artificial reproduction of the species may also be profitably used to stock extensive areas on which there are no loblolly-pine seed trees.

The first consideration is to determine whether to sow seed direct on the area to be reforested or whether to plant with nursery-grown or with wild-stock seedlings. The first will usually be the cheapest and therefore the best on sites to which it is adapted. Planting, however, is the surer method, and the only one to be recommended for Quality III sites and for all dry and droughty soil. Direct sowing is to be recommended only on uniformly fresh to moist soils, where it should be successful if properly carried out.

Direct Sowing.

In direct seeding of loblolly pine it is best to sow either in plowed furrows or in well-cultivated seed spots. Another method is broadcasting or scattering seed uniformly over an area, as in sowing wheat. This method is seldom if ever advisable, as it takes about five times as much seed per acre as the seed spot or furrow methods, and, to be successful, usually requires that the ground be harrowed over before and after the sowing.

If the area can be plowed the furrow method is best. Shallow furrows should be plowed from 6 to 8 feet apart, and from 10 to 15 seeds dropped in spots in the furrows at intervals of from 6 to 8 feet. Where it is impracticable to plow furrows, the next best thing is to sow from 10 to 15 seeds in well-cultivated spots 6 inches to a foot square, dug with a spade or grub hoe, and spaced from 6 to 8 feet apart each way. In each method the seed should be carefully covered with earth to a depth of not more than half an inch. Where the soil is dry and sandy, especial care should be taken to step on the spot after covering the seed, and the soil should be pressed down with the ball of the foot or else tamped with the bottom of a hoe. This will enable the seed to draw more moisture from the soil. The furrow and seed-spot methods require per acre from 6,000 to 18,000 seeds, or from one-third to one pound of seed, while for successful broadcasting from 3 to 5 pounds per acre would be necessary. When planting in furrows, it is best that these be made straight and at a uniform distance apart. When planting in seed spots, the rows can be made straight by placing upright poles on which to sight.

The best time for sowing the seed is shortly after growth ceases in the fall, but before the ground is much frozen, or as soon as the frost gets out of the ground in the spring to admit of cultivation. Loblolly seed takes from 1 to 3 months to sprout after suitable temperature conditions obtain, and often some of it holds over till the next season before germinating.

The cost per acre of sowing in plowed furrows or seed spots ranges from $2 to $5, depending upon cost of seed and labor, and spacing used: 50 cents to $1.50 for seed, [1]$1 to $2 for cultivation, and 50 cents to $1.50 for sowing.

Planting.

In planting loblolly pine it will usually be advisable to use nursery-grown stock. In some cases, however, wild stock seedlings can be advantageously used to supplement incomplete natural reproduction, as in transplanting seedlings from areas overstocked to nearby areas understocked.

The size and age of nursery stock it is best to use varies. On Qualities I and II soils 1 or 2 year old seedlings are usually successful. These can be planted either in the fall, at the end of the first or second season's growth, or set out in the spring following. On site Quality III it is always best to use 3-year-old stock which has been transplanted for two years in the nursery. It is best to use this kind of stock also on the better site qualities if there is a heavy undergrowth or growth of hardwood sprouts and seedlings with which the pine has to compete. In Quality I soils a spacing of 10 by 10 feet each way, or 436 trees per acre, is sufficient; for site Quality II, 8 by 8 feet spacing should be used, or 680 trees per acre; and for site Quality III, 6 by 6 feet, or 1,210 trees per acre. On moist to wet sites planting should not be done in the fall, unless the plants are pretty well mulched, because of the danger that the unrooted plant will be frost-thrown during the winter. On such sites spring planting is always advisable. In the fall the best time for planting is after growth has ceased; in the spring, as soon as the frost gets out of the ground.

The cost of growing loblolly pine nursery stock on a large scale [2] should be about as follows:

One-year seedlings	$0.75
Two-year seedlings	1.25
Three-year stock (two years transplanted)	3.00

The cost of handling the stock from the nursery to permanent plantations in the forest should be about as follows per 1,000:

One-year seedlings	$3.50
Two-year seedlings	4.50
Three-year stock (two years transplanted)	6.00

[1] Seed to be collected by party using it. If purchased from nursery, price would be much higher.

[2] In a nursery producing 500,000 or more plants a year, as shown by the work of the P. R. R. nursery at Morrisville, N. J. For a smaller nursery the cost would be somewhat higher, although a farmer will often be in a position to collect his own seed and grow a few thousand loblolly seedlings every year in garden at practically no expense.

The cost per acre, then, of growing and setting out stock of different ages, differently spaced, would be as follows:

Kind of stock.	Spacing.		
	6 by 6 feet.	8 by 8 feet.	10 by 10 feet.
1-year seedlings	$4.99	$3.13	$2.27
2-year seedlings	6.70	4.31	3.21
3-year stock (2 years transplanted)	10.26	7.08	5.61

It will be seen from the foregoing that where wide spacing is practiced and nursery stock is grown on a large scale locally, planting can sometimes be done as cheaply as direct sowing. Moreover, it is always much the surer method. The cost figures given are, of course, only applicable to operations properly planned and skillfully carried out.

ALTERNATION OF FOREST AND FARM CROPS.

There are large areas of rather poor sandy land throughout the region in which loblolly pine occurs which will produce good farm crops for a number of years after cleared of forest and brush, but the fertility of which it is expensive to maintain for any considerable length of time. Such land can sometimes be most profitably worked on a system of alternating a forest crop of loblolly pine, grown on a 40 to 50 year rotation, with the use of the land for farm crops for a period of from 10 to 15 years. The fertilizing effect on the soil in the growing of a timber crop is in this way taken advantage of for agricultural crops. In addition to this a new crop of loblolly pine can be established very easily on the area when worn out by farming. If there are sufficient loblolly-pine seed trees in the vicinity, the reproduction will spring up naturally on the abandoned field, and if not, the pine can be planted or sowed. This is a good method of establishing a loblolly-pine forest on land which before cultivation had no loblolly on it, and also one especially adapted for use by resident farmers with woodlands adjacent to their farms.

NURSERY WORK.[1]

Where extensive planting operations are to be carried on it is best to establish a forest nursery. The following are the essential points to be held in mind in this work:

Selection of Nursery Site.

A site should be selected if possible with a light, moderately fertile, well-drained, but uniformly fresh to moist soil, and located in the open where there will be the least danger from disturbance by birds,

[1] For detailed information on nursery work the reader is referred to Bulletin 76 of the Forest Service and Yearbook Reprint 376, of the Dept. of Agriculture.

stock, and rodents. A small nursery can most readily be established by taking a section of a well-cultivated vegetable garden. If the soil is droughty there should be facilities for watering it in dry weather. If the ground selected has not been cultivated for some time it should be thoroughly worked, and if lacking in fertility, should be enriched.

Seed Beds and Planting Seeds.

Before planting the seed, carefully prepared beds should be made, and the soil thoroughly worked, as for lettuce. Four feet wide and 24 feet long is the most convenient size for the beds. Parallel beds should be separated by walks 2 feet wide. Where the soil is light and dry, or very well drained, the beds can be on the same level with the walks, otherwise they should be elevated several inches. Planting in drills 4 inches apart, running crosswise of the bed, is the best method. By sowing 1 ounce of seed per 24 linear feet of drill, or about three-quarters of a pound per bed, it is safe to count on at least 3,000 one-year seedlings per bed, where proper attention is given to the work. This means 3,000 seedlings per 150 square feet of nursery space, including area in walks, or over 2,000,000 seedlings on a quarter acre. The seed should be sown in the spring, about the same time as early vegetables.

Care of Beds.

Beds should be kept as uniformly moist as possible, to insure germination. Ten weeks after planting most of the seeds which are going to sprout will be well up; weeding should then commence and be continued through the season. The beds should be provided with lath screens as soon as the seed is planted. These will keep the seed bed uniformly moist and secure early germination. The seedlings should be kept under partial shade the whole of the first season. Suitable screens can be made in frames "4 [1] by 12 feet, of 2 by 2 inch square sticks, across which laths are nailed, each lath alternating with an open space of the same width." These frames should be supported on posts so as to be about 18 inches above the seed bed. They should be removed only during cold, cloudy weather, when the seedlings need all the air possible to lessen the danger of their "damping off."

Transplanting Seedlings.

Where three-year-old stock is desired the seedlings should be transplanted at the end of the first season into nursery rows, spaced 4 to 6 inches apart in these, and allowed to grow two more seasons. Where two-year seedlings are desired it is unnecessary to transplant,

[1] From Yearbook Reprint 376, Dept. of Agriculture.

but the amount of seed sown in the drills should be reduced one-half, so that the seedlings will have more room in which to grow. Or, instead, the seed might be evenly and thinly broadcasted over the seed bed.

Growing Plant Stock on a Small Scale.

For the farmer who wishes to grow planting stock on a small scale the elaborate bed and its care, while the surest of success, is not altogether necessary. He can more easily establish a single row of seedlings in a fertile, well-drained section of his vegetable garden, cultivating and tending them as he would a crop of peas or beans, and without screening.

THINNINGS IN UNIFORM STANDS.

The returns possible from intermediate cuttings, or thinnings, of well-stocked uniform stands should be taken advantage of in the management of loblolly pine whenever there is a market for the material. The object of such thinnings is primarily to utilize material which otherwise would be lost through death and decay, and secondarily to improve the stand by removal of overtopped trees and some of the less desirable dominant trees, in this way concentrating the growth of the stand into a lesser number of the most desirable individuals. Where substantial returns can be realized from thinnings it amounts in effect to "eating the cake and at the same time having it," while improving its quality. Thinnings in understocked stands, which under present forest conditions are the rule, are not usually advisable.

In general, the rapidity of natural thinning, or dying out of overtopped trees, in loblolly-pine stands makes further thinning inadvisable unless the material cut can be profitably utilized.

It is best for the stand to commence thinning at an early age, that is, when 15 to 20 years old, and to repeat the thinning at intervals of from 5 to 10 years. Thinning in stands 15 to 30 years old can be made to include a larger number of undesirable trees from the dominant stand than in older stands. In the latter, thinnings should be confined almost exclusively to the removal of overtopped, unhealthy, dying, and dead trees. The thinning of loblolly-pine stands on moist to wet sites is more effective than on dry soil, because the natural dying off of overtopped trees is much slower in the former than in the latter.

Table 26 shows the increase in diameter on a wet site of a thinned as compared with an unthinned half-acre plot located in the same stand. The age of the stand in 1906, at the time of the first measurement and thinning, was 18 years, and in 1910, at the time of the second measurement, 22 years. The stand was unusually dense.

TABLE 26.—*Diameter growth due to thinning and proportion of trees cut and dying on thinned and unthinned plots. Growth in diameter on thinned and unthinned plots.*

Tree classes.[1]	Thinned plot.			Unthinned plot.		
	Total number of trees.[2]	Average diameter breasthigh.		Total number of trees.[2]	Average diameter breasthigh.	
		1906	1910		1906	1910
Dominant	195	4.6	5.8	234	4.6	5.5
Codominant	160	3.6	4.2	201	3.5	4.0
Intermediate	68	3.0	3.3	77	3.0	3.3
Suppressed	49	3.0	3.2	60	3.0	3.1
Other species	3	3.0	3.6	50	3.4	4.0
Total	474	.....	.....	622	.....	.....

[1] Under dominant and codominant are included all trees which go to form the upper or main crown cover: (1) Dominant—trees with well-formed crowns, receiving light on all sides; (2) codominant—trees with uneven crowns and crowded on the sides. The intermediate and suppressed classes include overtopped trees below the upper crown cover: (*a*) Intermediate—receiving some direct sunlight on tips of crowns; (*b*) suppressed—with tips of crowns shaded.

[2] Total number of trees alive in 1910. The average diameter given for 1906 is only for trees still alive in 1910.

Before the thinning in 1906 the thinned plot had 679 living trees and the unthinned plot 691 trees, as shown in the following classification, showing proportion of trees cut and dying:

Tree classes.	Thinned plot.				Unthinned plot.			
	Alive 1910.	Cut in 1906.	Died since 1906.	Total.	Alive 1910.	Cut in 1906.	Died since 1906.	Total.
Dominant	195	13	2	210	234	.....	3	237
Codominant	160	62	8	230	201	.....	21	222
Intermediate	68	33	18	119	77	.....	26	103
Suppressed	49	8	25	82	60	.....	17	77
Other species	2	32	4	38	50	.....	2	52
Total	474	148	57	679	622	.....	69	691

The beneficial result of thinning is very evident from the foregoing tables, both in the more rapid growth of the trees left in the thinned stand, and in the possible returns from the 148 trees cut in the 1906 thinning.

As a rule, thinnings in young stands 25 years or less in age should be heavy, that is, removing (1) all dead, dying, and unhealthy trees of all classes; (2) most suppressed and intermediate trees; (3) many codominant; (4) and some poorly formed dominant. In older stands as a rule only moderate thinnings should be made, removing only intermediate and suppressed trees, in addition to the dead, dying, and unhealthy of all classes.

In all thinnings two points should be aimed at: (1) To secure an even distribution of the most desirable trees with a suitable amount of growing space for each; (2) to preserve sufficient density of stand

to insure pruning of lateral branches and to keep the ground fairly well shaded in order to prevent heavy undergrowth from springing up and in order to keep the soil moist. Where large gaps are formed in the upper leaf canopy by the removal of unhealthy or otherwise undesirable dominant or codominant trees healthy overtopped trees should be left to protect the soil.

Thinnings should be made in the winter, when there is the least danger from destructive insects breeding in the slash. Further to lessen danger from insects it is always best to lop the tops of the trees and burn the brush.

IMPROVEMENT CUTTINGS IN MIXED STANDS.

Improvement cuttings in mixed stands, to favor loblolly pine, will often be advisable, especially for farmers with woodlots who can work in their woodlands at spare times during the winter. They are made, as their name implies, primarily to improve the quality composition of the stand, and may be conveniently classified under (1) cutting in young sapling stands which will yield little or no usable material, and (2) cuttings in older stands where the material removed is large enough to be of some use.

Cuttings in sapling stands 5 to 10 years old should consist in weeding, or the cutting of undesirable species, and cleanings, or the cutting of inferior individuals of desirable species. These are known as disengagement cuttings, the object being to free or disengage the crowns of the more desirable trees from injurious contact with or suppression by the less desirable. This can often be accomplished by simply topping the interfering saplings individually with one slash of a brush ax or a corn knife. It is not necessary to cut back inferior trees which are not interfering with the better individuals. One man should cover from one to two acres a day in this kind of work. Scattering large trees, which have been left in previous cuttings because worthless for anything but fuel, might also be cut at the same time.

In mixed irregular stands, cut over several times but with a large number of inferior trees remaining, under which considerable sapling and small pole growth of loblolly pine and other species has sprung up, there is often an excellent chance to make an improvement cutting which will greatly benefit the loblolly. All the large inferior trees should be cut, care being taken not to damage the young loblolly pine which it is wished to favor. Sometimes, in fact, it may be best simply to girdle the large trees and leave them standing. All young growth of inferior species which is overtopping the pine should also be cut. Besides benefiting the future stand, these cuttings should at least be productive of a large amount of cordwood.

FIG. 1.—A 9 TO 10 YEAR OLD STAND NOT YET READY FOR THINNING.

FIG. 2.—A 16-YEAR-OLD STAND READY FOR FIRST THINNING.

FULLY STOCKED YOUNG LOBLOLLY PINE STANDS.

FIG. 1.—TWENTY-ONE-YEAR-OLD STAND UNTHINNED.

FIG. 2.—AN ADJACENT STAND OF THE SAME AGE PROPERLY THINNED 5 YEARS BEFORE, WHEN 6 CORDS PER ACRE WERE REMOVED.

THINNED AND UNTHINNED STANDS OF LOBLOLLY.

SUMMARY OF TREATMENT FOR TYPICAL STANDS.

The following is a summary of treatment to be recommended for typical existing stands in which loblolly pine occurs, the object being to favor the species and usually to make it or to maintain it as the predominating tree.

LOBLOLLY ON MOIST TO WET SOILS, INCLUDING FLATS, BOTTOMS, AND SWAMPS.

(1) *Mature stands of hardwoods with a slight admixture of loblolly pine.*—The object here should be to remove the old stand in such a way as to secure as much natural reproduction as possible of loblolly. The scattered seed tree method (as described on p. —) will be the simplest one to use, clean cutting all the hardwoods and leaving from four to six loblolly seed trees per acre well distributed over the area. Disturbance of the forest floor in logging will assist reproduction of pine. The use of fire to improve seed-bed conditions is also beneficial, but not entirely necessary. Surface burning should be carried on before the seed-fall of loblolly pine, which means any time before the first of November. Fires after seed-fall should be confined to piles of brush made in logging. Where the pine is not seeding at the time of the cutting, it will probably be better to remove the hardwoods in two cuttings, the first one opening up around the loblolly trees so as to cause them to produce abundant seed two years or so later, and a second cutting during a good pine seed year, or after the pine reproduction has taken place. The first cutting should leave enough hardwoods to keep the ground uniformly shaded, in order to prevent a luxuriance of hardwood undergrowth from springing up.

(2) *Culled-over to severely cut-over mixed hardwoods and pine, the former predominating.*—In these stands most of the mature pine has been removed, but there is often a considerable number of small pine poles and a good amount of pine reproduction, which should be favored by making general improvement and disengagement cuttings. All mature hardwoods should be cut out; all trees of undesirable species, such as red maple, mature and immature, should be cleaned out, especially where suppressing pine; sapling and small pole hardwoods of good form and desirable species should be left wherever not interfering with pine; loblolly pine should be planted or sowed in vacant spots.

(3) *Pure stands of merchantable loblolly pine on old fields or in small groups in original forests.*—Cut, using the scattered seed-tree method, or else the method of successive thinnings (see pp. 30 and 31).

(4) *Pure stands of immature loblolly pine.*—Should be thinned as recommended on pages 38 to 40.

(5) *Mixed immature stands of pine and hardwoods.*—Should be thinned as recommended on page 40.

(6) *Mixed sapling stands of pine and hardwoods.*—Give disengagement cutting, freeing the tops of the pines by cutting back hardwoods overtopping them.

Loblolly Pine on Fresh to Dry Uplands.

(1) *In mixed mature stands with other pines and hardwoods, chiefly oaks.*—On light soils cut clean, leaving loblolly seed trees, as described on page 30. Burn area before seed-fall to improve seed bed. On dry heavy soils shortleaf pine should be favored in preference to loblolly, since it will reproduce better on such sites.

(2) *Cut-over mixed pine and hardwoods, with mixed reproduction.*—Clean cut all mature trees, and make disengagement cuttings favoring pine in the sapling reproduction. Plant or sow with loblolly pine any vacant places which occur on light soils, and with shortleaf pine on heavy soils.

(3) *Immature stands of pure pine.*—Thin as recommended on pages 38 to 40.

(4) *Mixed immature stands of pine and hardwoods.*—Thin as recommended on page 40.

(5) *Idle land with a dry light soil not restocking naturally to loblolly pine.*—Should be planted with 3-year-old nursery stock (2-year transplants). On dry, heavy soils it is better to use shortleaf pine.

APPENDIX A.

NOMENCLATURE.

Loblolly pine is known by a number of different names in different sections of the country, and frequently even in the same locality, according as it occurs as old growth or second growth, or in the forest or on old fields. The name "loblolly" originated in the Gulf States and was applied to a thicket swamp in which this pine is common. Below is given a list of common and local names by which the tree is known in Delaware, Maryland, and Virginia, many of which are also often applied to other species of pines.

Longleaf, longstraw, or longtag pine, applied where associated with shortleaf, pitch, or scrub pines.

Shortleaf, shortstraw, or shorttag pine, applied where associated with the real longleaf pine (*Pinus palustris*).

Swamp pine, slash pine, yellow pine, usually applied to old growth.

Rosemary pine, applied to good quality old growth.

Oldfield pine, where it occurs on old fields.

Black or black-bark pine, sap pine, bastard pine, applied to second growth.

Foxtail pine, in Maryland, common on the "western shore."

Indian pine, Virginia pine, North Carolina pine, in Virginia.

Delaware pine, in Delaware.

Maryland pine, in Maryland.

DISTINGUISHING CHARACTERISTICS OF THE TREE.

Loblolly pine is one of 13 species of yellow pine native to the eastern United States. The woods of these species are very similar, with no characteristics which can be invariably relied on for distinguishing them, yet the trees themselves have certain distinct botanical characteristics by which they can always be identified. Loblolly pine can readily be distinguished by its foliage and cones; it has a slightly glaucous foliage with three needles, from 4 to 8 inches long, occurring in a close, elongated sheath; the needles are slender, stiff, rigidly pointed, channeled, strongly keeled on the upper side, slightly twisted, and pale green in color; the cones are from 3 to 5 inches long, oblongovate to ovate and broadly conical in shape, occurring on the stem singly or in twos and threes, and nearly sessile; the cones have hard, woody scales with strong recurved prickles on the ends.

The salient characteristics of other pine associated with loblolly in the region which serve to readily distinguish them from it are as follows: Shortleaf pine (*Pinus echinata*) has straight needles (three in a sheath) $1\frac{1}{2}$ to 4 inches long, and cones 1 to $2\frac{1}{2}$ inches in length. Pitch pine (*Pinus rigida*) has needles more decidedly and uniformly twisted than those of loblolly, occurring three in a sheath, from 3 to 5 inches in length, while its cones are shorter, being more than 1 to 3 inches long, and uniformly ovate-conical or broadly conical in shape. Pitch pine is also apt to have bunches of needles sprouting from the clear bole of the tree, which loblolly never has. Scrub pine (*Pinus virginiana*) can be easily distinguished from loblolly by the fact that its needles occur in twos instead of threes; they have a decided twist and are from 1 to $2\frac{1}{2}$ inches in length, broad and decidedly sessile on the stems. Longleaf pine (*Pinus palustris*) can never be confused with loblolly pine, on account of its extremely long needles, from 8 to 18 inches in length, while its cones are from 6 to 10 inches long.

CHARACTERISTICS OF THE WOOD.[1]

PHYSICAL PROPERTIES.

Average weight of kiln-dried wood, 31 pounds per cubic foot.

Average weight of kiln-dried wood lumber, 300 pounds per 1,000 board feet.

Specific gravity varies from 0.40 to 0.80.

Specific gravity most frequent range, 0.45 to 0.55; spring wood, about 0.40, summer wood, about 0.95; so that the weight of the wood increases with the larger proportion of summer wood.

Ash, 0.25 per cent of dry wood.

Fuel value, 73 per cent of that of white oak.

Breaking strength (modulus of rupture), 5,600 pounds per square inch, average. (77 per cent of that of longleaf yellow pine according to Sargent.)

Factor of stiffness (modulus of elasticity), 1,300,000 pounds per square inch, average. (77 per cent of that of longleaf yellow pine according to Sargent.)

Appearance of grain seen in cross section, variable, mostly very coarse; 3 to 12 rings, average 6 to the inch in structural lumber, generally wider than short leaf, which averages 12.

General character and qualities, medium heavy, strong, and tough; grain coarse, even; summer wood broad, resin more abundant than in shortleaf, but less than in longleaf; resin passages numerous, not prominent; medullary rays numerous, obscure; heartwood orange yellow to light brown, the very thick sapwood light yellow or often nearly white; not at all durable sapwood, but takes preservative treatment readily; wood of "rosemary" pine close-grained, less resinous, lighter, with much thinner sap.

SHRINKAGE AND KILN DRYING.

The wood of loblolly pine, in common with that of other of the southern pines, shrinks about 10 per cent in cross section of volume (neglecting longitudinal shrinkage) when dried from a green to an oven-dry state. From 3 to 4 per cent of this shrinkage occurs along the radius, and from 6 to 7 per cent around the circumference. In green loblolly lumber there is about 25 per cent of moisture. In the usual air-dry condition, from 12 to 15 per cent of moisture still remains in the wood, so that the shrinkage from the green to the air-dry condition is only a trifle over half of that from the green to the absolutely dry state. Wood that has shrunk will return to its original size if soaked.

The larger proportion of loblolly pine lumber is kiln dried before leaving the sawmill yard. This drying prevents "bluing," lessens the shipping weight, and reduces the tendency to further shrinkage.

For successful kiln drying, both the wood and the water it contains should be raised to the temperature at which the drying is to take place. If the wood is slowly heated and the surface moisture carried away, the surface will become entirely dry before the interior is heated, and the lumber will shrink and check on the surface. Surface drying should be delayed in the kiln by retaining the moisture first vaporized while the heat penetrates to the interior. Steam may be used to wet the wood and raise it to the drying temperature. When the inside as well as the surface of the wood is at the proper temperature, drying may proceed, care being taken to replace the heat lost from the wood by vaporization by the heat of the kiln.

[1] Taken from Bulletin 99 and Circular 164 of the Forest Service.

APPENDIX B.

TABLES.

CUT OF LUMBER IN THE REGION.

Table 27 gives in detail by counties the cut of lumber in the region covered by this bulletin.

TABLE 27.—*Total amount of lumber cut of all species, and the proportion of yellow pine, in counties in which loblolly pine occurs in Delaware, Maryland, and Virginia.*

[Compiled from the census returns for 1909.]

State and county.	Land area.	Total cut.	Yellow pine cut.
	Sq. mi.	*M bd. ft.*	*M bd. ft.*
Delaware	1,960	55,440	.....
Kent	615	5,118	2,087
Sussex	911	46,849	36,680
Loblolly counties' totals	1,526	51,967	38,767
Maryland	9,860	267,939	.....
Anne Arundel	425	2,707	1,064
Calvert	222	8,244	1,620
Caroline	320	19,017	13,334
Charles	451	8,038	2,850
Dorchester	608	20,193	16,482
Kent	281	1,474	128
Prince Georges	482	5,043	1,081
Queen Annes	376	4,518	2,383
St. Marys	372	10,904	8,507
Somerset	362	12,535	9,549
Talbot	286	6,673	3,685
Wicomico	365	24,756	22,215
Worcester	487	19,438	15,077
Loblolly counties' totals	5,037	143,540	97,975
Virginia	40,125	2,101,716	1,221,691
Accomac	478	40,403	33,196
Amelia	355	18,446	13,917
Brunswick	529	78,510	73,010
Caroline	562	28,837	25,802
Charles City	183	4,070	3,675
Chesterfield	484	39,599	35,574
Dinwiddie	521	84,138	76,006
Elizabeth City	50	.....	.....
Essex	277	28,331	26,318
Fairfax	433	15,413	7,541
Gloucester	253	20,623	19,508
Goochland	296	6,262	3,980
Greenesville	288	37,570	37,228
Hanover	478	17,156	13,778
Henrico	273	22,594	7,453
Isle of Wight	352	21,615	19,445
James City	159	19,603	17,633
King and Queen	336	22,259	19,669
King George	183	6,891	5,030
King William	246	2,330	2,270
Lancaster	137	10,196	8,643
Louisa	529	21,351	18,069
Lunenburg	471	48,632	37,330
Mathews	92	4,884	4,538
Mecklenburg	640	47,415	41,266
Middlesex	156	24,467	23,176
Nansemond	393	81,436	75,900
New Kent	233	18,148	16,689
Norfolk	425	139,008	120,277
Northampton	232	14,724	13,034
Northumberland	235	33,742	25,119
Nottoway	304	19,448	16,037
Powhatan	284	9,396	7,339
Prince George	302	3,059	2,016
Princess Anne	285	8,801	5,342
Prince William	353	24,074	18,081
Richmond	188	15,682	13,318
Southampton	609	95,474	78,324
Spottsylvania	401	34,466	31,995
Stafford	285	25,701	22,764
Surry	292	70,483	68,622
Sussex	490	20,486	19,162
Warwick	85	2,229	2,030
Westmoreland	245	6,381	5,347
York	134	1,020	883
Loblolly counties' totals	14,530	1,295,353	1,116,334

YIELD PER ACRE BY GRADES.

Table 28 shows the yield per acre in board feet by grades to be expected from pure, even-aged, fully stocked, unmanaged stands of loblolly pine at different ages, and on different qualities of land, when cutting all trees 5 inches and over in diameter

breasthigh. Table 29 shows the same thing in per cent of grades instead of in board feet. All trees 5 and 6 inches in diameter, breasthigh, were scaled as entirely flitch, and this grade is confined exclusively to these diameter classes. The other six grades given apply to trees 7 inches and over in diameter, and comprise the main grades used by the North Carolina Pine Association in the manufacture and sale of North Carolina pine rough lumber.

TABLE 28.— *Yield per acre in board feet by grades from pure, even-aged, fully-stocked, unmanaged stands of loblolly pine of different ages.*

QUALITY I.

Age.	Flitch.	Yield per acre.							Basis.
		No. 1.	No. 2.	No. 3.	No. 4.	1 and 2 bark strips.	Box bark strips.	Total.	
Years.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Plots.*
10	1,200							1,200	7
15	3,290			188	940	94	188	4,700	17
20	3,071	166	83	913	3,237	333	498	8,300	6
25	2,178	363	363	1,815	6,050	484	847	12,100	4
30	1,272	795	636	2,703	8,586	795	1,113	15,900	2
35	591	1,379	985	3,546	11,229	786	1,182	19,700	4
40		1,904	1,666	4,522	13,566	952	1,190	23,800	2
45		2,810	2,529	5,339	15,455	843	1,124	28,100	
50		3,586	3,260	6,520	17,278	978	978	32,600	
Total									42

QUALITY II.

10	400							400	7
15	2,296			84	308	56	56	2,800	20
20	2,484	54	54	486	1,782	216	324	5,400	19
25	1,944	162	162	1,053	3,807	405	567	8,100	3
30	1,650	330	330	1,760	5,610	550	770	11,000	6
35	1,380	690	552	2,346	7,176	690	966	13,800	2
40	1,162	996	830	2,988	8,798	830	996	16,600	5
45	780	1,365	1,170	3,510	10,725	780	1,170	19,500	4
50		2,034	1,582	4,294	12,656	904	1,130	22,600	1
Total									67

QUALITY III.

10									6
15	1,131			26	91	26	26	1,300	4
20	1,904			140	560	84	112	2,800	4
25	2,332	44		352	1,320	176	264	4,400	3
30	2,460	120	60	600	2,220	240	300	6,000	
35	2,233	308	154	924	3,311	308	462	7,700	5
40	1,786	470	376	1,410	4,418	376	564	9,400	
45	1,130	678	565	1,808	5,989	452	678	11,300	1
50		1,072	938	2,412	7,638	536	804	13,400	1
Total									24

Cut by circular saw, ¼-inch kerf.

TABLE 29.—*Per cent of grades to be expected from pure, even-aged, fully-stocked stands of loblolly pine of different ages cut into North Carolina pine rough lumber.*

QUALITY I.

Age.	Flitch.	Grade.						Basis.
		No. 1.	No. 2.	No. 3.	No. 4.	1 and 2 bark strips.	Box bark strips.	
Years.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Plots.*
10	100							7
15	70			4	20	2	4	17
20	37	2	1	11	39	4	6	6
25	18	3	3	15	50	4	7	4
30	8	5	4	17	54	5	7	2
35	3	7	5	18	57	4	6	4
40		8	7	19	57	4	5	2
45		10	9	19	55	3	4	
50		11	10	20	53	3	3	
Total								42

QUALITY II.

10	100							7
15	82			3	11	2	2	20
20	46	1	1	9	33	4	6	19
25	24	2	2	13	47	5	7	3
30	15	3	3	16	51	5	7	6
35	10	5	4	17	52	5	7	2
40	7	6	5	18	53	5	6	5
45	4	7	6	18	55	4	6	4
50		9	7	19	56	4	5	1
Total								67

QUALITY III.

10	100							6
15	87			2	7	2	2	4
20	68			5	20	3	4	4
25	53	1		8	30	3	5	3
30	41	2	1	10	37	4	5	
35	29	4	2	12	43	4	6	5
40	19	5	4	15	47	4	6	
45	10	6	5	16	53	4	6	1
50		8	7	18	57	4	6	1
Total								24

Cut by circular saw, ¼-inch kerf.

LOG-VOLUME TABLES.

Tables 30 to 35 inclusive are log-volume tables (for logs from trees under 50 years in age), based on measurements of logs with corresponding mill tallies of lumber actually sawed out. The North Carolina measurements were taken at a mill only 5 miles from the Virginia line, and are entirely adaptable to the region under consideration.

Tables 30 and 31 show the actual mill cut in board feet and percentage of the different North Carolina Pine Association grades cut from butt, middle, and top logs of different diameters and lengths.

Table 32 is based on the cut of a portable mill in Somerset County, Md., and runs slightly higher than Table 30, due largely to the fact that the lumber was not so carefully manufactured, it being sold ungraded and mill run.

Table 33 shows the cut of small logs when sawed into crate flitch—i. e., plank 2¾-inch thick, having one waney edge. The width measured in scaling is the average width on the narrow face. A comparison of this table with the preceding (Table 32) shows that logs cut out more board feet of lumber when sawed into flitch than when sawed into boards. The value of flitch per 1,000 board feet, however, is only three-quarters that of inch lumber.

Table 34 shows the cut in board feet of flitch and of inch lumber from 4-foot logs for crate and box lumber. Measurements taken on 1 cord of stacked bolts, the diameter and amount of lumber actually cut being recorded separately for each bolt, give the following results: Bolts ranging 3 to 6 inches in diameter between bark at the small end will cut out 510 board feet of flitch per cord, or if sawed into inch boards will cut out 390 board feet; bolts 6 to 9 inches in diameter will saw out 600 board feet per cord, or if cut into inch boards will cut 500 board feet; a mill crew of four (one sawyer, one engineer and fireman combined, and two men to help in handling the bolts and the lumber) can readily saw up 5 to 10 cords a day, yielding 2,500 to 3,000 board feet of flitch, or 2,000 to 2,500 board feet of inch lumber in case sawed into the latter.

Table 35 indicates how much more lumber can be sawed from logs cut into four sections than when sawed as 12-foot logs. The percentage increase of the former over the latter is especially marked in the case of logs of small diameters, but makes little difference in large diameters.

TABLE 30.—*Mill cut in board feet of butt, middle, and top logs of different diameters and lengths by mill in Gates County, N. C.*

BUTT LOGS.

Diameter inside bark at small end.	Length of log (feet).						Basis.
	6	8	10	12	14	16	
	Volume (board feet).						
Inches.							*Logs.*
4	2	3	4	5	5	6	.....
5	4	5	6	8	9	10	.....
6	6	7	9	11	13	15	.....
7	8	11	13	16	18	21	14
8	11	15	19	23	26	30	36
9	15	20	25	30	35	40	55
10	19	25	32	38	44	50	48
11	23	31	39	47	55	62	43
12	29	38	48	57	67	76	28
13	35	46	58	69	81	92	26
14	41	55	69	82	96	110	8
15	48	64	80	96	112	128	6
16	56	74	93	111	130	149	3
Total	.....	.....	.....	.....	.....	.....	267

MIDDLE LOGS.

4	2	3	4	5	6	6	.....
5	4	5	7	8	9	10	3
6	6	8	10	12	14	16	19
7	8	11	14	17	19	22	44
8	11	15	19	23	26	30	54
9	15	20	25	30	35	40	61
10	19	26	32	38	45	51	37
11	24	33	41	49	57	65	24
12	30	40	50	60	71	81	18
13	36	49	61	73	85	97	8
14	43	57	72	86	100	115	5
Total	.....	.....	.....	.....	.....	.....	273

TOP LOGS.

3	1	1	1	1	2	2	.....
4	2	3	4	5	5	6	.....
5	4	6	7	8	10	11	19
6	6	8	10	12	15	17	58
7	9	12	15	18	20	23	84
8	12	16	20	24	28	32	63
9	15	20	26	31	36	41	41
10	19	26	32	39	45	52	18
11	24	32	40	48	56	64	10
Total	.....	.....	.....	.....	.....	.....	293

These figures are based on straight and slightly crooked logs only.
Of the logs tallied, 65 were 12-foot, 117 were 14-foot, and 651 were 16-foot logs.
Cut by circular saw, ⅛-inch kerf.

TABLE 31.—*Per cent of grades from butt, middle, and top logs of different diameters and lengths cut into North Carolina pine rough lumber by mill in Gates County, N. C.*

BUTT LOGS.

Diameter inside bark at small end.	Grade.						Basis.
	No. 1.	No. 2.	No. 3.	No. 4.	1 and 2 bark strips.	Box bark strips.	
Inches.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Logs.*
7	5.2	3.4	32.2	47.8	7.5	3.9	14
8	10.3	8.4	27.4	43.4	6.8	3.7	38
9	16.5	13.1	22.7	40.3	5.8	1.6	54
10	14.6	15.2	32.9	31.5	5.2	.6	49
11	16.6	10.0	29.0	40.0	3.5	.9	43
12	21.1	16.5	29.4	28.5	2.9	1.6	28
13	23.0	19.0	32.6	22.6	2.8	.....	26
14	26.9	15.1	25.1	30.1	2.8	.....	8
15	26.7	12.5	36.5	20.9	3.4	.....	6
16	25.4	28.0	32.0	10.3	3.0	1.3	4
Total	.....	.....	.....	.....	.....	.....	270

MIDDLE LOGS.

5	.....	.....	.....	76.6	.....	23.4	3
6	.....	.....	6.1	76.9	4.6	12.4	19
7	2.8	1.1	7.8	80.7	.7	6.9	45
8	2.5	2.4	9.4	78.4	2.8	4.5	56
9	4.4	3.6	6.2	80.6	2.8	2.4	63
10	5.9	6.5	13.0	68.9	3.8	1.9	37
11	7.4	6.6	14.1	68.1	3.1	.7	23
12	8.2	10.0	16.2	63.2	1.7	.7	18
13	13.7	9.8	27.2	47.4	1.9	.....	8
14	19.4	18.0	6.4	55.3	.9	.....	5
15	5.7	14.5	5.5	69.1	3.6	1.6	2
Total	.....	.....	.....	.....	.....	.....	279

TOP LOGS.

5	.....	.....	.....	79.9	2.0	18.1	20
6	.....	.....	.....	93.6	.8	5.6	58
7	0.2	0.2	1.3	90.2	2.3	5.8	84
8	.5	.....	.8	94.1	1.3	3.3	63
9	.1	.6	2.7	91.4	.2	5.0	44
10	.....	1.5	3.2	92.6	1.1	1.6	18
11	1.0	2.4	3.4	92.1	.....	1.1	11
12	.....	3.5	3.8	92.7	.....	.....	3
Total	.....	.....	.....	.....	.....	.....	301

Cut by circular saw, ¼-inch kerf.

TABLE 32.—*Mill cut in board feet of butt, middle, and top logs of different diameters and lengths by mill, in Somerset County, Md.*

BUTT LOGS.

Diameter inside bark, small end.	Length of log (feet).						Basis.
	6	8	10	12	14	16	
	Volume (board feet).						
Inches.							*Logs.*
4	3	4	5	5	6	7	8
5	4	6	7	8	10	11	41
6	6	8	11	13	15	17	58
7	9	12	16	19	22	25	48
8	13	17	21	25	30	34	18
9	17	22	28	34	39	45	2
10	22	29	36	43	50	58	6
11	27	36	45	54	63	72	.....
12	32	43	54	65	76	86	1
13	38	51	64	77	89	102	.....
14	44	59	74	89	104	118	.....
15	51	68	85	102	120	137	.....
16	58	78	97	116	136	155	.....
Total	.....	.....	.....	.....	.....	.....	182

MIDDLE LOGS.

4	2	3	4	5	6	6	5
5	4	5	7	8	10	11	18
6	7	9	11	13	16	18	59
7	10	13	17	20	23	27	39
8	14	19	23	28	33	37	9
9	18	24	30	36	42	48	4
10	22	30	37	44	52	59	3
11	27	36	45	54	63	72	.....
12	32	43	54	65	76	87	1
13	39	51	64	77	90	103	.....
14	45	60	75	90	105	120	.....
Total	.....	.....	.....	.....	.....	.....	138

TOP LOGS.

3	1	1	1	1	2	2	1
4	2	3	4	5	6	7	37
5	5	6	8	9	11	12	39
6	7	10	12	15	17	20	10
7	11	14	18	21	25	28	1
8	14	19	24	29	33	38	.....
9	18	25	31	37	43	49	.....
10	23	31	39	46	54	62	.....
11	28	37	47	56	65	75	.....
Total	.....	.....	.....	.....	.....	.....	88

These figures are based on straight and slightly crooked logs only.
Of the logs tallied, 311 were 10-foot, 94 were 12-foot, and 3 were 14-foot logs.
Cut by circular saw, ¼-inch kerf.

TABLE 33.—*Cut of small logs when sawed into crate flitch* [1] *by mill in Somerset County, Md.*

BUTT LOGS.

Diameter inside bark, small end.	Length of log (feet).				Basis.
	6	8	10	12	
	Volume (board feet).				
Inches.					*Logs.*
4	3	5	6	7	10
5	5	7	9	10	20
6	8	10	13	15	5
Total					35

MIDDLE LOGS.

4	3	4	5	6	2
5	6	7	9	11	14
6	8	11	14	17	10
Total					26

TOP LOGS.

3	2	3	4	5	3
4	4	5	6	7	41
5	5	7	9	11	11
Total					55

[1] Sawed into flitch, i. e., plank $2\frac{3}{4}$ inches thick, having one waney edge. The width measured in scaling is the average width on the narrow side.
Cut by circular saw, $\frac{1}{4}$-inch kerf.

TABLE 34.—*Cut of flitch and 1-inch boards from logs of different diameters and 4 feet long by a mill in Wicomico County, Md.*

Diameter inside bark, small end.	Volume of flitch in 4-foot logs.[1]	Volume of 1-inch boards in 4-foot logs.[2]	Diameter inside bark, small end.	Volume of flitch in 4-foot logs.[1]	Volume of 1-inch boards in 4-foot logs.[2]
Inches.	*Board feet.*	*Board feet.*	*Inches.*	*Board feet.*	*Board feet.*
2.0	0.3	0.3	7.5	9.5	8.0
2.5	.8	.6	8.0	10.8	9.4
3.0	1.3	1.0	8.5	12.4	10.7
3.5	1.8	1.4	9.0	14.0	12.1
4.0	2.4	1.8	9.5	15.9	13.5
4.5	3.2	2.4	10.0	17.9	15.0
5.0	4.0	3.0	10.5	20.0	16.5
5.5	4.8	3.7	11.0	22.4	18.1
6.0	5.8	4.6	11.5	25.0	19.7
6.5	7.0	5.6	12.0	28.0	21.4
7.0	8.2	6.7			

[1] Basis, mill cut of 168 logs.
[2] Basis, mill cut of 30 logs.
Cut by circular saw, $\frac{1}{4}$-inch kerf.
Flitch is plank $2\frac{3}{4}$ inches thick, having one waney edge.

TABLE 35.—*Comparison of mill-cut logs cut into 4-foot sections and into 12-foot lengths, by mills in Somerset and Wicomico Counties, Md.*

BUTT LOGS.

Diameter inside bark small end.	Inch boards.		Increase (not curved).	Flitch.		Increase (not curved).
	Volume scaled as one 12-foot log.	Volume scaled as three 4-foot logs.		Volume scaled as one 12-foot log.	Volume scaled as three 4-foot logs.	
Inches.	*Bd. ft.*	*Bd. ft.*	*Per cent.*	*Bd. ft.*	*Bd. ft.*	*Per cent.*
4	5	6.6	32.0	7	8.9	27.1
5	8	10.8	35.0	10	14.1	41.0
6	13	16.0	23.1	15	19.9	32.7
7	19	23.1	21.6	.....	.....	.....
8	25	30.6	22.4	.....	.....	.....
9	34	39.9	17.4	.....	.....	.....
10	43	48.8	13.5	.....	.....	.....
11	54	57.9	7.2	.....	.....	.....

MIDDLE LOGS.

4	5	8.4	68.0	6	9.8	63.3
5	8	10.5	31.3	11	13.7	24.5
6	13	16.0	23.1	17	19.9	17.1
7	20	21.9	9.5	.....	.....	.....
8	28	30.3	8.2	.....	.....	.....
9	36	38.9	8.1	.....	.....	.....
10	44	47.9	8.9	.....	.....	.....
11	54	57.2	5.9	.....	.....	.....

TOP LOGS.

3	1	4.5	350.0	5	7.0	40.0
4	5	8.3	66.0	7	11.0	57.1
5	9	12.1	34.4	11	15.5	40.9
6	15	18.0	20.0	.....	.....	.....
7	21	26.1	24.3	.....	.....	.....
8	29	31.2	7.6	.....	.....	.....
9	37	39.9	7.8	.....	.....	.....
10	46	50.0	8.7	.....	.....	.....
11	56	59.2	5.7	.....	.....	.....

TREE VOLUME TABLES.

Tables 36 to 44, inclusive, are tree volume tables (for trees under 50 years in age), based on the taper table (Table 45) and the log volume tables (Tables 30 to 35). Tables 36 and 38 give the volume in cubic feet of trees of different diameters and heights, with and without bark. Table 37 gives the per cent of volume subtracted for bark from the figures given in Table 36 to get Table 38.

Tables 39, 40, and 41 show the volume in board feet of trees of different diameters and heights, 39 based on actual cut of logs and trees followed through the mill, 40 based on logs and trees scaled by the Scribner log rule, and 41 scaled by the Doyle log rule. It will be seen that the mill-cut table ranges over 10 per cent higher than the Scribner rule table, and in comparison with Doyle rule table ranges 100 to 500 per cent higher on trees under 12 inches in diameter breasthigh, and 25 to 100 per cent higher on trees over 12 inches in diameter. The Doyle rule is commonly used in logging operations in southeastern Virginia, and is very much to the advantage of the mill man when cutting small trees.

Table 42 indicates the actual mill cut of small trees of different diameters and heights when cut into 4-foot lengths and sawed into flitch or into inch boards. A comparison of this table with Table 39 shows how much more lumber can be obtained when cutting small trees into very short sections.

Tables 43 and 44 show the grades of North Carolina pine rough lumber, in board feet and per cent, actually cut from trees of different diameters 30 to 50 years in age, based on measurements of logs and trees taken in the woods with corresponding mill tallies of lumber sawed out. These measurements were taken in northeastern North Carolina, 5 miles from the Virginia line.

TABLE 36.—*Volume in cubic feet, including bark, of trees of different diameters and heights, from measurements taken in Worcester and Somerset Counties, Md.*

Diameter breast-high.	Height of tree (feet).														Basis.
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	
	Merchantable volume, including bark (cubic feet).														
Inches.															*Trees.*
3	0.5	0.5	0.6	0.6	0.6	0.6	.....	.....	.....	.....	.....	.....	.....	.....	3
4	.8	.9	1.1	1.4	1.5	1.7	1.8	2.0	.....	.....	.....	.....	.....	.....	2
5	.....	.....	1.8	2.1	2.4	2.7	3.0	3.4	3.7	.....	.....	.....	.....	.....	9
6	.....	.....	2.6	3.0	3.4	3.8	4.4	4.8	5.4	5.8	.....	.....	.....	.....	62
7	.....	.....	.....	4.0	4.7	5.4	6.1	6.8	7.5	8.1	8.8	9.4	.....	.....	77
8	.....	.....	.....	5.1	6.1	7.0	8.0	8.9	9.7	10.7	11.7	12.7	13.6	.....	81
9	.....	.....	.....	.....	7.0	8.4	9.9	11.2	12.5	13.7	15.0	16.2	17.3	.....	47
10	.....	.....	.....	.....	.....	10.5	12.1	13.8	15.3	16.9	18.5	19.8	20.9	22.0	31
11	.....	.....	.....	.....	.....	.....	14.2	16.3	18.3	20.2	22.0	23.9	25.7	27.5	18
12	.....	.....	.....	.....	.....	.....	16.3	18.8	21.2	23.6	26.0	28.1	30.1	32.1	15
13	.....	.....	.....	.....	.....	.....	19.6	22.6	25.5	28.0	30.4	32.6	34.9	37.0	9
14	.....	.....	.....	.....	.....	.....	.....	26.9	29.8	32.4	35.1	37.8	40.3	42.9	2
15	.....	.....	.....	.....	.....	.....	.....	.....	32.8	36.0	39.0	42.2	45.4	48.3	5
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	41.0	44.4	47.8	51.1	54.2	8
17	.....	.....	.....	.....	.....	.....	.....	.....	.....	47.0	50.5	54.0	57.6	61.0	1
18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	56.2	60.2	64.1	67.8	1
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	61.0	65.6	70.2	74.7	1
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	71.7	77.0	82.4	
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	372

TABLE 37.—*Per cent of bark in total volume of trees of different diameters in Worcester and Somerset Counties, Md.*

Diameter, breast-high.	Bark.	Diameter, breast-high.	Bark.	Diameter, breast-high.	Bark.	Diameter, breast-high.	Bark.
Inches.	*Per cent.*	*Inches.*	*Per cent.*	*Inches.*	*Per cent.*	*Inches.*	*Per cent.*
2	41	7	28	12	21	17	17
3	38	8	26	13	20	18	16
4	35	9	24	14	19	19	16
5	32	10	23	15	18	20	15
6	30	11	22	16	18		

TABLE 38.—*Volume in cubic feet, exclusive of bark, of trees of different diameters and heights from measurements of 372 trees in Somerset and Worcester Counties, Md.*

Diameter breast-high.	Height of tree (feet).										
	30	35	40	45	50	55	60	65	70	75	80
	Peeled merchantable volume (cubic feet).										
Inches.											
3	0.4	0.4	0.4	.....	.....	.....	.....	.....	.....	.....	.....
4	.9	1.0	1.1	1.2	1.3	.....	.....	.....	.....	.....	.....
5	1.4	1.6	1.8	2.0	2.3	.....	.....	.....	.....	.....	.....
6	2.1	2.4	2.7	3.1	3.4	3.8	4.1	.....	.....	.....	.....
7	2.9	3.4	3.9	4.4	4.9	5.4	5.9	.....	.....	.....	.....
8	3.8	4.5	5.2	5.9	6.6	7.2	7.9	8.7	9.4	.....	.....
9	.....	.....	6.4	7.5	8.5	9.5	10.4	11.4	12.3	.....	.....
10	.....	.....	8.1	9.3	10.6	11.8	13.0	14.2	15.2	16.1	16.9
11	.....	.....	.....	.....	12.7	14.3	15.8	17.2	18.7	20.1	21.5
12	.....	.....	.....	.....	14.9	16.8	18.7	20.6	22.3	23.9	25.5
13	.....	.....	.....	.....	.....	20.4	22.4	24.3	26.1	27.9	29.6
14	.....	.....	.....	.....	.....	24.0	26.1	28.3	30.5	32.5	34.6
15	.....	.....	.....	.....	.....	.....	29.5	32.0	34.6	37.2	39.6
16	.....	.....	.....	.....	.....	.....	33.9	36.7	39.5	42.2	44.8
17	.....	.....	.....	.....	.....	.....	.....	42.1	45.0	48.0	50.8
18	.....	.....	.....	.....	.....	.....	.....	47.2	50.6	53.9	57.0
19	.....	.....	.....	.....	.....	.....	.....	51.7	55.6	59.5	63.3
20	.....	.....	.....	.....	.....	.....	.....	.....	61.0	65.5	70.1

Scaled to a top diameter limit of 1.5 inch inside bark. Stump height, 1 foot.
Based on taper curves, diameter measurements taken every 4 feet.

TABLE 39.—*Volume in board feet of trees of different diameters and heights based on actual mill cut in Maryland.*

Diameter breast-high.	Height of tree (feet).										
	30	35	40	45	50	55	60	65	70	75	80
	Volume (board feet).										
Inches.											
[1] 5	5	6	6	7	8	8	.....	.....	.....	.....	.....
[1] 6	8	10	12	14	16	18	20	.....	.....	.....	.....
7	7	10	12	14	17	19	21	.....	.....	.....	.....
8	11	14	18	22	25	28	31	33	.....	.....	.....
9	.....	20	26	30	34	39	43	47	.....	.....	.....
10	.....	.....	34	39	44	50	57	63	69	75	82
11	.....	.....	.....	48	55	64	72	80	89	98	105
12	.....	.....	.....	58	67	78	89	99	110	120	130
13	.....	.....	.....	68	80	94	107	121	133	145	157
14	.....	.....	.....	.....	93	111	127	143	157	170	185
15	.....	.....	.....	.....	.....	129	150	167	182	198	213
16	.....	.....	.....	.....	.....	.....	178	195	212	228	243
17	.....	.....	.....	.....	.....	.....	206	225	243	261	276
18	.....	.....	.....	.....	.....	.....	.....	258	276	294	311
19	.....	.....	.....	.....	.....	.....	.....	290	309	330	350
20	.....	.....	.....	.....	.....	.....	.....	.....	344	366	390

[1] Five and six inch trees scaled as if cut into flitch; i. e., plank $2\frac{3}{4}$ inches thick, having one waney edge. Width measured in scaling is the average width on narrow face. Diameter inside bark at top 3.5 inches.

Based on taper curves, scaled as 8, 12, and 16 foot logs.
Diameter inside bark of top, 4.5 inches.
Stump height assumed, 1 foot.
Circular saw, $\frac{1}{4}$-inch kerf.

TABLE 40.—*Volume in board feet of trees of different diameters and heights in Maryland, scaled by the Scribner log rule.*

Diameter breast-high.	Height of tree (feet).								
	40	45	50	55	60	65	70	75	80
	Volume (board feet).								
Inches.									
7	6	8	10	12	14	.....	.....	.....	.....
8	13	17	20	23	26	29	32	.....	.....
9	21	26	30	35	39	43	47	.....	.....
10	30	36	41	47	53	58	64	69	74
11	.....	.....	52	59	66	74	81	90	98
12	.....	.....	63	72	81	91	100	111	121
13	.....	.....	74	86	98	109	121	133	145
14	.....	.....	.....	.....	116	130	143	157	170
15	.....	.....	.....	.....	137	152	167	182	196
16	.....	.....	.....	.....	160	176	194	210	226
17	.....	.....	.....	.....	.....	.....	224	241	258
18	.....	.....	.....	.....	.....	.....	255	274	292
19	.....	.....	.....	.....	.....	.....	288	308	326
20	.....	.....	.....	.....	.....	.....	323	342	362

Based on taper curves, scaled as 8, 12, and 16 foot logs.
Diameter inside bark of top, 5.5 inches.
Stump height assumed, 1 foot.

TABLE 41.—*Volume in board feet of trees of different diameters and heights in Maryland, scaled by the Doyle log rule.*

Diameter breast-high.	Height of tree (feet).								
	19	45	50	55	60	65	70	75	80
	Volume (board feet).								
Inches.									
8	3	4	5	.....	.....	.....	.....	.....	.....
9	7	8	9	11	13	15	16	.....	.....
10	11	13	15	18	20	23	27	30	33
11	.....	.....	22	26	30	34	40	44	49
12	.....	.....	30	36	42	48	55	62	69
13	.....	.....	40	48	57	65	74	82	90
14	.....	.....	.....	.....	74	84	94	104	114
15	.....	.....	.....	.....	94	105	118	130	141
16	.....	.....	.....	.....	116	129	146	159	171
17	.....	.....	.....	.....	.....	.....	176	189	201
18	.....	.....	.....	.....	.....	.....	208	221	233
19	.....	.....	.....	.....	.....	.....	240	254	267
20	.....	.....	.....	.....	.....	.....	272	288	302

Based on taper curves, scaled as 8, 12, and 16 foot logs.
Diameter inside bark of top, 5.5 inches.
Stump height assumed, 1 foot.

TABLE 42.—*Mill cut in board feet from small trees of different diameters and heights when cut into 4-foot sections and sawed into flitch or into 1-inch boards by mills in Wicomico County, Md.*

Mill cut of trees cut up into 4-foot logs and sawed into inch boards and flitch.

Diameter breast-high.	Height of tree (feet).								
	30	35	40	45	50	55	60	65	70
	Volume in board feet, cut into inch boards.								
Inches.									
4	3	3	3	4	4	.....	.....	.....	.....
5	5	6	7	8	9	.....	.....	.....	.....
6	9	11	12	14	16	17	19	.....	.....
7	13	15	18	20	23	26	29	.....	.....
8	18	21	25	29	33	37	42	47	52
	Volume in board feet, cut into flitch.[1]								
4	4	4	4	5	5	.....	.....	.....	.....
5	7	8	9	10	12	.....	.....	.....	.....
6	12	14	16	18	20	23	25	.....	.....
7	17	20	23	26	30	34	38	.....	.....
8	23	27	32	37	42	47	53	60	67

[1] Sawed into flitch, i. e., plank, 2½ inches thick, having one waney edge. The width measured in scaling is the average width on the narrow side.

Based on taper curves, scaled as 4-foot logs.
Diameter inside bark of top, 2.5 inches.
Stump height assumed, 1 foot.
Circular saw, ⅛-inch kerf.

TABLE 43.—*Number of board feet by grades of North Carolina pine rough lumber sawed from trees of different diameters by mill in Gates County, N. C.*

Diameter breasthigh.	Height of tree.	Grade.						Total.	Basis.
		No. 1.	No. 2.	No. 3.	No. 4.	1 and 2 bark strips.	1 and 2 bark strips.		
		Volume (board feet).							
Inches.	*Feet.*								
7	47	.....	.....	2.5	16.7	2.0	2.7	23.9	.....
8	50	.....	.....	6.5	19.4	2.1	3.1	31.1	1
9	54	1.3	0.9	8.4	23.5	2.3	3.6	40.0	7
10	57	2.8	2.3	9.5	30.0	2.5	4.0	51.1	45
11	60	4.8	4.0	11.4	39.4	2.9	4.3	66.8	77
12	62	7.3	6.0	14.7	52.1	3.4	4.6	88.1	65
13	64	10.8	8.6	20.8	68.0	4.0	4.7	116.9	71
14	66	15.6	12.6	28.8	84.9	4.8	4.6	151.3	55
15	68	22.5	19.1	37.3	100.0	5.5	4.4	188.8	29
16	70	30.9	25.0	45.6	112.1	6.2	4.0	223.8	29
17	71	39.8	28.2	53.7	122.2	6.9	3.5	254.3	14
18	72	49.1	29.9	62.0	131.0	7.5	3.0	282.5	6
19	74	58.3	30.9	70.6	139.0	8.1	2.4	309.3	5
20	75	67.5	31.7	79.5	146.4	8.8	1.8	335.7	1

TABLE 44.—*Per cent of North Carolina pine grades cut from trees of different diameters by mill in Gates County, N. C.*

Diameter breast-high.	Grade.						Volume.	Basis.
	No. 1.	No. 2.	No. 3.	No. 4.	1 and 2 bark strips.	1 and 2 bark strips.		
Inches.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Bd. ft.*	*Trees.*
7	.....	.....	10.4	69.9	8.4	11.3	24	.....
8	.....	.....	20.9	62.4	6.7	10.0	31	1
9	3.3	2.2	21.0	58.8	5.7	9.0	40	7
10	5.5	4.5	18.6	58.7	4.9	7.8	51	45
11	7.2	6.0	17.1	59.0	4.3	6.4	67	77
12	8.3	6.8	16.7	59.1	3.9	5.2	88	65
13	9.2	7.4	17.8	58.2	3.4	4.0	117	71
14	10.3	8.3	19.1	56.1	3.2	3.0	151	55
15	11.9	10.1	19.8	53.0	2.9	2.3	189	29
16	13.8	11.2	20.4	50.1	2.7	1.8	224	29
17	15.7	11.1	21.1	48.0	2.7	1.4	254	14
18	17.4	10.6	21.9	46.4	2.6	1.1	283	6
19	18.9	10.0	22.8	44.9	2.6	.8	309	5
20	20.1	9.5	23.7	43.6	2.6	.5	336	1
Total.	.....	.....	.....	.....	.....	.....	.....	405

Cut by circular saw, ¼-inch kerf.

FORM TABLE.

Table 45 shows in detail form or taper of trees of different diameters and heights and 10 to 50 years in age.

TABLE 45.—*Diameters at different heights above the ground of trees of different diameters and heights, from measurements taken on loblolly pine in Somerset and Worcester Counties, Md.*

30-FOOT TREES.

Diameter breast-high.	Height above ground (feet).																Basis.
	0.5	1.0	1.5	4.5	5	9	13	17	21	25	29	33	37	41	45	49	
	Diameter inside bark (inches).																
Inches.																	*Trees.*
3	3.1	2.9	2.7	2.5	2.5	2.1	1.8	1.4	1.1	0.6	0.1	.....	.....	.....	.....	.....	2
4	4.1	3.9	3.7	3.3	3.3	2.9	2.5	2.1	1.6	.9	.2	.....	.....	.....	.....	.....	.....
5	5.2	4.9	4.7	4.1	4.1	3.7	3.3	2.7	2.0	1.2	.3	.....	.....	.....	.....	.....	1
6	6.3	5.9	5.7	5.0	5.0	4.5	4.0	3.3	2.5	1.5	.3	.....	.....	.....	.....	.....	1
7	7.3	6.9	6.7	5.9	5.8	5.3	4.7	4.0	3.0	1.8	.4	.....	.....	.....	.....	.....	1
8	8.4	8.0	7.8	6.7	6.6	6.1	5.4	4.6	3.5	2.1	.4	.....	.....	.....	.....	.....	2
Total.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7

40-FOOT TREES.

3	3.1	2.9	2.7	2.3	2.3	2.0	1.8	1.6	1.4	1.2	0.9	0.6	0.3	.....	.....	.....	1
4	4.1	3.9	3.7	3.2	3.2	2.9	2.7	2.4	2.1	1.9	1.5	1.1	.5	.....	.....	.....	2
5	5.2	4.9	4.7	4.1	4.0	3.7	3.5	3.1	2.8	2.5	2.0	1.4	.7	.....	.....	.....	5
6	6.3	5.9	5.7	5.0	4.9	4.6	4.2	3.9	3.5	3.0	2.5	1.8	.9	.....	.....	.....	17
7	7.3	6.9	6.7	5.8	5.8	5.4	5.0	4.6	4.1	3.6	3.0	2.1	1.0	.....	.....	.....	22
8	8.4	8.0	7.8	6.7	6.6	6.2	5.8	5.3	4.8	4.2	3.5	2.5	1.2	.....	.....	.....	16
9	9.5	9.1	8.8	7.5	7.5	7.0	6.5	6.0	5.5	4.8	4.0	2.8	1.3	.....	.....	.....	5
10	10.6	10.1	9.8	8.4	8.3	7.7	7.2	6.7	6.1	5.4	4.5	3.2	1.5	.....	.....	.....	.....
Total.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	68

50-FOOT TREES.

4	4.1	3.9	3.7	3.1	3.1	2.9	2.7	2.6	2.5	2.3	2.1	1.7	1.4	1.0	0.6	0.1	.....
5	5.2	4.9	4.7	4.0	4.0	3.7	3.6	3.4	3.3	3.0	2.7	2.4	1.9	1.4	.8	.2	3
6	6.3	5.9	5.7	4.9	4.9	4.6	4.4	4.2	4.0	3.7	3.4	3.0	2.4	1.7	1.0	.2	39
7	7.3	6.9	6.7	5.8	5.7	5.5	5.2	4.9	4.8	4.5	4.1	3.6	2.9	2.1	1.2	.3	43
8	8.4	8.0	7.8	6.7	6.7	6.4	6.0	5.7	5.5	5.1	4.8	4.2	3.4	2.5	1.4	.3	52
9	9.5	9.1	8.8	7.6	7.6	7.2	6.8	6.5	6.2	5.8	5.4	4.8	3.9	2.9	1.6	.3	22
10	10.6	10.1	9.8	8.5	8.4	8.0	7.6	7.2	7.0	6.5	6.0	5.4	4.4	3.2	1.9	.4	15
11	11.6	11.2	10.8	9.4	9.3	8.9	8.4	8.0	7.7	7.2	6.7	5.9	4.9	3.7	2.1	.4	4
12	12.8	12.2	11.8	10.3	10.2	9.7	9.1	8.7	8.3	7.8	7.2	6.5	5.4	4.0	2.3	.5	3
13	13.9	13.3	12.9	11.2	11.1	10.4	9.9	9.4	9.0	8.4	7.8	7.0	5.8	4.4	2.6	.5	.....
Total.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	181

TABLE 45.— *Diameters at different heights above the ground of trees of different diameters and heights, from measurements taken on loblolly pine in Somerset and Worcester Counties, Md.*—Continued.

60-FOOT TREES.

Diameter, breast-high.	Height above ground (feet).																							Basis.
	0.5	1.0	1.5	4.5	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65	69	73	77	
	Diameter inside bark (inches).																							
Inches.																								*Trees.*
6	6.3	5.9	5.7	4.9	4.9	4.7	4.5	4.4	4.2	4.1	3.9	3.6	3.2	2.7	2.1	1.6	1.0	0.4						5
7	7.3	6.9	6.7	5.8	5.8	5.6	5.4	5.2	5.0	4.9	4.7	4.3	3.8	3.2	2.6	1.9	1.3	.6						11
8	8.4	8.0	7.8	6.7	6.7	6.5	6.3	6.0	5.8	5.6	5.4	4.9	4.4	3.7	3.0	2.3	1.5	.7						10
9	9.5	9.1	8.8	7.7	7.7	7.4	7.1	6.8	6.6	6.3	6.1	5.6	4.9	4.2	3.5	2.7	1.8	.8						20
10	10.6	10.1	9.8	8.6	8.6	8.2	7.9	7.6	7.3	7.1	6.7	6.2	5.5	4.7	3.9	3.0	2.0	.9						12
11	11.6	11.2	10.8	9.5	9.5	9.1	8.7	8.4	8.1	7.8	7.4	6.8	6.1	5.3	4.3	3.4	2.3	1.0						5
12	12.8	12.2	11.8	10.4	10.4	10.0	9.6	9.2	8.8	8.5	8.0	7.4	6.6	5.7	4.8	3.7	2.5	1.1						8
13	13.9	13.3	12.9	11.3	11.3	10.8	10.4	10.0	9.6	9.2	8.7	8.0	7.2	6.2	5.2	4.1	2.8	1.2						3
14	15.1	14.3	13.9	12.1	12.1	11.7	11.2	10.8	10.4	9.9	9.3	8.6	7.7	6.7	5.6	4.4	3.0	1.4						
15	16.2	15.3	15.0	13.1	13.0	12.5	12.0	11.6	11.1	10.6	10.0	9.2	8.3	7.2	6.0	4.8	3.3	1.5						1
16	17.3	16.4	16.0	13.9	13.8	13.3	12.8	12.4	11.9	11.3	10.6	9.8	8.8	7.7	6.4	5.1	3.6	1.6						
Total																								75

70-FOOT TREES.

8	8.4	8.0	7.8	6.8	6.8	6.6	6.5	6.3	6.1	5.9	5.7	5.4	5.2	4.8	4.4	3.8	3.3	2.6	1.9	1.1	0.2			1
9	9.5	9.1	8.8	7.8	7.8	7.6	7.3	7.1	6.9	6.7	6.4	6.1	5.8	5.5	5.0	4.4	3.8	3.1	2.2	1.3	.3			
10	10.6	10.1	9.8	8.7	8.7	8.5	8.2	8.0	7.7	7.5	7.2	6.9	6.6	6.1	5.6	5.0	4.3	3.5	2.5	1.5	.3			4
11	11.6	11.2	10.8	9.7	9.6	9.4	9.1	8.8	8.6	8.3	8.0	7.7	7.3	6.8	6.2	5.5	4.7	3.9	2.8	1.7	.3			7
12	12.8	12.2	11.8	10.6	10.5	10.2	9.9	9.7	9.4	9.1	8.8	8.4	8.0	7.5	6.8	6.1	5.2	4.2	3.1	1.9	.4			2
13	13.9	13.3	12.9	11.5	11.4	11.1	10.7	10.4	10.1	9.8	9.5	9.1	8.7	8.1	7.5	6.6	5.7	4.6	3.5	2.1	.4			5
14	15.1	14.3	13.9	12.4	12.3	11.9	11.6	11.2	10.9	10.6	10.3	9.9	9.4	8.8	8.1	7.2	6.1	5.0	3.7	2.2	.5			1
15	16.2	15.3	15.0	13.3	13.2	12.8	12.3	12.0	11.7	11.4	11.0	10.6	10.0	9.4	8.6	7.7	6.6	5.4	4.0	2.4	.5			3
16	17.3	16.4	16.0	14.1	14.1	13.6	13.1	12.7	12.4	12.1	11.7	11.2	10.7	10.0	9.2	8.2	7.0	5.8	4.3	2.5	.5			6
17	18.5	17.5	17.0	15.0	15.0	14.4	14.0	13.6	13.2	12.7	12.3	11.9	11.3	10.6	9.7	8.7	7.5	6.1	4.5	2.7	.6			1
18	19.6	18.5	18.1	15.9	15.9	15.2	14.7	14.3	13.9	13.5	13.1	12.6	12.0	11.3	10.3	9.2	7.9	6.5	4.8	2.9	.6			1
Total																								31

10	10.6	10.1	9.8	8.8	8.8	8.7	8.5	8.2	8.0	7.7	7.3	7.0	6.6	6.1	5.6	5.0	4.4	3.8	3.1	2.5	1.8	1.2	0.5	.....
11	11.6	11.2	10.8	9.8	9.7	9.5	9.3	9.0	8.8	8.5	8.2	7.8	7.3	6.8	6.2	5.6	4.9	4.3	3.5	2.8	2.1	1.3	.6	2
12	12.8	12.2	11.8	10.7	10.7	10.4	10.1	9.9	9.6	9.3	8.9	8.5	8.0	7.5	6.8	6.2	5.5	4.7	3.9	3.1	2.3	1.5	.6	2
13	13.9	13.3	12.9	11.6	11.6	11.2	10.8	10.6	10.4	10.0	9.7	9.2	8.7	8.1	7.5	6.8	6.0	5.3	4.4	3.5	2.5	1.6	.7	1
14	15.1	14.3	13.9	12.5	12.5	12.1	11.8	11.5	11.2	10.8	10.4	9.9	9.4	8.8	8.1	7.4	6.6	5.7	4.8	3.9	2.9	1.8	.8	1
15	16.2	15.3	15.0	13.5	13.4	12.9	12.6	12.3	11.9	11.5	11.1	10.6	10.1	9.5	8.8	8.0	7.2	6.3	5.3	4.2	3.1	2.0	.9	1
16	17.3	16.4	16.0	14.4	14.3	13.7	13.3	13.0	12.7	12.2	11.8	11.3	10.8	10.2	9.5	8.7	7.8	6.8	5.8	4.7	3.5	2.2	1.0	2
17	18.5	17.5	17.0	15.3	15.2	14.5	14.1	13.8	13.4	13.0	12.5	12.0	11.4	10.8	10.1	9.2	8.4	7.4	6.3	5.2	3.9	2.5	1.1	.....
18	19.6	18.5	18.1	16.1	16.0	15.4	14.9	14.6	14.2	13.7	13.2	12.7	12.1	11.4	10.7	9.9	8.9	7.8	6.7	5.4	4.1	2.6	1.1	.....
19	20.8	19.6	19.1	17.0	16.9	16.2	15.7	15.4	15.0	14.5	13.9	13.3	12.7	12.0	11.3	10.4	9.4	8.3	7.1	5.8	4.4	2.8	1.2	1
20	22.0	20.6	20.2	17.9	17.8	17.0	16.5	16.2	15.8	15.2	14.6	14.0	13.3	12.6	11.8	11.0	10.0	8.9	7.6	6.2	4.7	3.1	1.3	.....
Total																								10

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 12

Contribution from the Forest Service, Henry S. Graves, Forester.
October 11, 1913.

USES OF COMMERCIAL WOODS OF THE UNITED STATES.

BEECH, BIRCHES, AND MAPLES.

By Hu Maxwell, *Expert.*

INTRODUCTION.

The three genera, beech, birch, and maple, which include 18 commercial species, besides several species or varieties too small or too scarce to be of commercial importance, form a group closely related. This relationship, however, is commercial rather than botanical. The woods of all have several points of similarity, such as hardness, strength, and susceptibility of fine polish, and in the main their uses are similar. They grow usually in the same regions, and they are often lumbered and milled almost as though they were a single wood, but the resulting lumber is piled and sold separately. It is not unusual in New England, the Appalachian region, and the Lake States for lumbermen to speak of beech, birch, and maple as "the hardwoods," thereby placing them in a group by themselves, separate from oak, elm, gum, and the rest. This is especially true when beech, birch, and maple go to chemical plants manufacturing charcoal, wood alcohol, acetates, and other by-products. These woods in 1909 constituted more than 90 per cent of all the hardwoods employed in distillation in the United States. They made up, also, a large but unknown percentage of the country's hardwood flooring, material for furniture and agricultural implements, and interior finish for houses. In a variety of small commodities they hold first place.

Though there is a general similarity in the properties and qualities of this group of woods, yet each species has its individuality, and in some ways is different from the others, and has different or special uses.

BEECH.

(*Fagus atropunicea.*)

PHYSICAL PROPERTIES.[1]

Weight of dry wood.—44.71 pounds per cubic foot of dry wood (Sargent).

Specific gravity.—0.6883 (Sargent).

Ash.—0.51 per cent of weight of dry wood (Sargent).

Fuel value.—92 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—16,100 pounds per square inch, or 128 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—1,697,800 pounds per square inch, or 128 per cent that of white oak (Sargent).

Very hard, tough, strong, not durable in contact with the soil; difficult to season; checks in drying; takes beautiful polish; medullary rays broad and very conspicuous; color varies with soil, but is usually dark red; sapwood nearly white.

Height, 75 to 100 feet; diameter, 1 to 4 feet.

SUPPLY.

Only one species of beech (*Fagus atropunicea*) grows naturally in the United States, but it is known by different names. Red beech and white beech refer, respectively, to the heartwood and sapwood of this tree, the contrast between the two being marked. The name ridge beech should be regarded as local, for the tree is not confined to ridges more than to bottom lands. The tree known as blue beech or water beech belongs to a different genus (*Carpinus caroliniana*); and the purple-leaved, pendulous-branched species frequently seen in parks and cemeteries is not a native of this country, but is the European beech (*Fagus sylvatica*).

Few trees in this country have a wider commercial range than beech, and in practically every locality where it grows it is cut for market. It ranges from the Gulf of Mexico into eastern Canada, and is found in most regions east of a line drawn from northern Wisconsin to Trinity River, Texas. In 1909 it was cut for lumber in 29 States, and the total output was 511,240,000 board feet, an increase of nearly 90,000,000 feet since 1907. The total remaining stand in the United States has been roughly estimated at from 17 to 20 billion feet, but from the nature of its distribution anything better than a general approximation is impossible. It occasionally forms pure stands, but it is also widely scattered among other species over an immense region. It was once much more abundant than it now is, for in practically all the forested regions of the eastern half of the United States, where farms have been cleared, beech was destroyed

[1] The physical values given for the different woods discussed in this bulletin are largely those of Sargent, and in many cases do not agree with values for similar properties obtained in tests by the Forest Service. Since the Forest Service tests are not yet complete, however, Sargent's data are given in order that a general comparison may be made between the different woods. Engineers and others wishing to obtain accurate values for the mechanical properties will, of course, not use this bulletin for that purpose.

to make room for crops. It was one of the woods least used by pioneers, and until comparatively recent years little attempt was made to save or utilize it. Though much less abundant than formerly, the tree is almost as widely distributed as it ever was. It has not, like shortleaf pine, for example, contracted its limits under the pressure of land clearing and lumber operations. It is a prolific seed bearer, and sprouts vigorously from roots and stumps, characteristics which greatly assist it in holding its ground. The nuts were formerly devoured by countless millions of wild pigeons, and since the annual visits of these migratory birds have ceased the quantity of seed left to germinate is much greater, though it is not possible to determine whether this has resulted in any marked increase in the number of young beech trees.

EARLY USES.

Early records in this country do not make frequent mention of the use of beech, though it was abundant nearly everywhere.[1]

The pioneer settlers who fenced their farms with rails had a well-grounded prejudice against beech because it was hard to split and decayed very quickly when exposed to the weather. It was, therefore, generally classed as worthless for fences. The discovery was made, however, that when under water and subjected to friction, as in mills, it lasted longer than almost any other wood. Axles and shafts for water wheels were made of it. It did not decay if submerged and the water did not soften the wood where the gudgeons and bearings rubbed on each other. No large quantity was demanded by millwrights, for the mills of those days were small, but the wood filled an important place.

Aside from its place in mill wheels the wood had other early uses. In the early glass factories the soldering of handles on carboys, jugs, pitchers, and dishes was performed by aid of a wooden tool, for which beech was the best material because of its freedom from injurious acids which would spoil the work.

The charcoal burners near old-time iron furnaces were the first to send a beech commodity to market on a somewhat extensive scale. Writing in 1749, Peter Kalm said that, next to black pine (*Pinus rigida*), the best charcoal for smithing purposes in the vicinity of Albany, N. Y., was made from beech. The wood filled other impor-

[1] In Europe and Asia an earlier record is claimed for beech than for any other wood, even antedating the sycamore and cypress of Egypt. The words "book" and "beech" were synonymous in some of the earliest written languages coming into Europe, due to the practice of writing on thin beech strips. The existence of the root of the word in Sanscrit has been taken as strong evidence that the wood was used for writing material in central Asia before the migration of the ancestors of the Germanic and Slavonic races westward into Europe. It has been taken as proof also that the alphabets of northern Europe came across the Caucasus Mountains and not by way of the Mediterranean Sea. In beech, therefore, we probably have the oldest existing name of a wood in the world.

tant places in the primitive blacksmith shop. It is very strong and stiff and was preferred as handles for heavy forge hammers. The wood was frequently demanded in the construction of bellows, another indispensable adjunct of the blacksmith shop. Here, too, it was strength and stiffness that gave it a place.

The wood is difficult to work in the carpenter shop and is not especially attractive in color or figure, yet it was sometimes selected when a handsome high-grade article was demanded. Among heirlooms, dating from the time of the Dutch settlers in New York, a carved spoon rack cut out of beech has come down to the present time.

Doubtless by far the greatest use of beech during the two centuries following the earliest settlements on the Atlantic coast was for fuel. It was convenient almost everywhere, and the farmers procured it easily. The large open fireplaces then common consumed enormous quantities of fuel, much of it beech.

ARTICLES REQUIRING FREEDOM FROM TASTE.

Woods which are free from objectionable taste find place in the manufacture of commodities which come in contact with foodstuffs, and beech has long been one of the chief woods so employed. Built-up butchers' blocks are constructed of beech, though not as many as of maple, and for the same reason meat boards, cutting tables in meat-packing houses, and skewers are made of this wood. Lard tubs, butter boxes and pails, and the beaters for ice-cream freezers are other commodities for which beech serves admirably. For ice-cream beaters the persistent hardness of the wood when subjected to attrition and abrasion while wet gives it peculiar fitness. Sugar hogsheads are made of beech, partly because it is a tasteless wood and partly because it has great strength. It is an excellent material for churns. Refrigerators, kitchen safes, and kitchen tables are made of beech in consideration of its freedom from taste and also because the wood is little affected by water. A large class of woodenware, including veneer plates, dishes, boxes, paddles, scoops, spoons, and beaters, belongs to the kitchen and pantry, and beech is one of the common woods of which they are made. Beech picnic plates are made by millions, a single machine turning out 75,000 a day.

It is customary in some parts of the country to filter cider through a mat of beech shavings to improve the taste and deepen the color.

AGRICULTURAL IMPLEMENTS.

The range of implements, machines, and apparatus about the farm, in the manufacture of which beech holds an important position, is wide and varied. In most instances it is employed because of its strength and stiffness. Frequently, however, its cheapness is the

principal consideration. Vehicle makers take it for wagon hubs, sand boards, bolsters, fellies, and sometimes for tongues, though for this last use it is not considered equal to hickory or good ash. It endures severe strain, but if it breaks it snaps short, while ash and hickory do not. The chief defect in a beech wagon hub or felly is the tendency of the wood to speedy decay when alternately wet and dry. It is sufficiently hard to hold the spokes in the mortises, though many other woods fail in that respect.

Fanning-mill frames and parts of windmills, thrashing machines, feed cutters, hay tedders, stackers, ensilage cutters, and many other farm implements are of beech. It is employed for its strength, and sometimes, where it is subjected to friction, because it wears smooth. Garden, lawn, and grain rollers are often of this wood, its weight being one of the properties which fit it for such implements. It is made use of for hayracks and as stanchions in dairy farms. In spite of its weight it is employed for grain shovels and scoops, although lighter woods are often given preference. Beech is one of the best woods for hames because one of the strongest, though metal is largely taking the place of wood for this purpose.

LAUNDRY APPLIANCES.

Beech enters largely into nearly all kinds of wooden laundry appliances, from large stationary tubs down to clothespins. In some cases it is employed because it is plentiful and cheap, but in others for its fitness. Naturally, much of the laundry machinery comes in contact with water, and wooden parts must be able to stand it. Beech meets that requirement. Some of the old-style washboards were wholly of wood, the ridges or corrugations, constituting the rubbing surface, being cut in a solid board. When it was made of wood beech was the best material, because it stood the wear. The wood is still employed in washboards, but is not so essential as formerly. The domestic washing machines which have taken the washboard's place in many homes often have a ridged or corrugated surface against which the clothes are rubbed by machinery. This corrugated surface and the dolly that does the rubbing are frequently of beech.

Clothespins are small articles, but the number made is enormous. In some factories beech is the only wood employed, but several other woods contribute to the country's supply. The remarkable cheapness of clothespins is possible because of the high development of the machines which make them. Squares of wood of the proper size are fed into automatic lathe machines through a hopper, much as grain was passed to the buhrs in an old-time mill. The lathe gives them the required shape, and they are then conveyed to other machines, where the slots are cut by circular saws. After that they are

dried in kilns and delivered to revolving hot-air cylinders, in which they are polished by soapstone mixed with them.

Ironing-board and sleeve-board makers draw some of their material from beech, but seldom all of it. The frames are often of this wood, but the board on which the smoothing is done is generally of some softer wood, such as white pine, cottonwood, yellow poplar, or basswood. A number of other articles classed as laundry appliances are manufactured wholly or in part of beech. Clothes bars, clotheshorses, clothes-drying frames, and curtain stretchers are among them. Other woods are also employed, and the use of beech for these commodities is in most instances due more to its cheapness than to any quality fitting it especially for the purpose. Towel racks and clothes hangers are a little further removed from the laundry, but belong in the same general class of articles.

FURNITURE.

Beech has never been much employed as an outside visible wood, because it has no pronounced grain or figure to make it attractive. Its place is in frames and interior work, where it gives substantial service. It is well fitted for slides along which drawers are moved in and out. It wears smooth, the grain being so uniform that friction seldom develops inequalities. When thoroughly seasoned it absorbs moisture in a smaller degree than almost any other American wood, and this property is important in a wood employed for slides or for drawers which move along them. There is little shrinking or swelling due to atmospheric changes, and consequently little annoyance from drawers sticking fast.

In recent years many styles of filing cabinets and cases have been put upon the market. When this class of office furniture appeared a large demand for beech was created, for its fitness for much of the work was at once recognized. In addition to drawer slides, backs, and bottoms, it was made into partitions, lining, and particularly frames and braces. The tracks on which the slides of extension tables move are often of beech. It has come to be used to some extent in almost all kinds and grades of furniture. Heavy beech veneer—sometimes three or five ply—is a common material for chair bottoms; the wood forms rounds and spindles of cheap and medium grades, and sometimes is nearly or quite the sole material in the cheap hall, camp, steamer, tent, and picnic chairs. It is made into rockers for chairs of more ambitious design, and caster rollers of beech are admirably adapted to service under beds, bureaus, chiffoniers, and other heavy furniture.

The stiffness of beech commends it to the maker of high-grade furniture, but there it is employed largely in built-up panels, and for sides, ends, and tops. Beech veneer is the invisible part, and

some more fashionable or attractive wood is laid over it. Beech dowels are used in the construction of table tops, counter tops, and other large pieces to fasten them together.

Bed slats of this wood are in demand in many furniture factories. They are cheap and stiff. Beech is listed among woods employed in marquetry or pattern work built up of blocks of different colored woods laid over some cheaper material. The color of beech is mild and subdued, and when artistically combined with other woods the effect is pleasing.

Church pews are often made in part of beech; and sometimes, on account of its color, it is the visible wood, particularly for the ends.

FLOORING AND FIXTURES.

A great deal of beech is used for flooring, and it ranks after maple and oak among the hardwoods so employed. In ordinary floors it wears as well, or nearly as well, as maple, and it has the advantage of shrinking and swelling less than most woods. Its best service is perhaps given in factory and warehouse floors, where usage is rough and wear is great. The wheels of hand trucks produce little effect on a well-seasoned beech floor.

The same qualities which lead to the use of beech in marquetry commend it for parquet flooring. It is regularly employed in that way, but it is not as important as are some of the darker and whiter woods, since it does not contrast so well.

Manufacturers of office, bank, and store fixtures employ beech for much of the hidden framework in counters, show cases, cabinets, and shelving. The line separating fixtures from interior finish is not clearly defined, and beech enters largely into both. It is seen in stair work, wainscoting, molding, spindles, brackets, and carved columns and other pieces. It is frequently made into window screens, and less frequently, because of its weight, into screen doors.

In practically all of the uses found for beech the heartwood is given preference. The sapwood is seldom desired. It is claimed by some manufacturers that the value of beech lumber would be increased and its uses extended if sawmills would exercise greater care in separating the sap from the heart lumber.

MISCELLANEOUS.

Beech has a long list of miscellaneous uses and enters into a great variety of commodities. In every region where it grows in commercial quantities it is made into boxes, baskets, and crating. Beech baskets are chiefly employed in shipping fruit, berries, and vegetables, and are of thin lumber, generally veneer, and intended to be used only once. In Maine thin veneer of beech is made specially for the

Sicily orange and lemon trade. This is shipped in bulk and the boxes are made abroad.

Large quantities of beech broom handles are on the market. The wood is not as popular as maple, because of darker color and a little more weight, but its service is as satisfactory. Makers of carpet sweepers find place for some high-grade beech, and it enters more largely into brush backs than any other American wood, due to its ability to hold its shape while alternately wet and dry. Its use, however, is confined to cheaper grades of brushes, and it does not compete with mahogany and ebony.

Beech, because it is smooth, hard, and elastic, holds an important place in the manufacture of children's games and toys. It is one of the best woods for rolling hoops. It serves also as drum hoops and as corners for various gaming boards. The entire crokinole board is often of beech. Rockers for hobby horses, hand sleds, and parts of toy wagons are commonly made of this wood. The stereopticon is a small apparatus and does not require much wood, but beech appears to be used more than all others combined.

There are few musical instruments in which wood is used which do not find beech serviceable for some part. Draw stops in organs, the framework of pianos and pipe organs, the shells of drums, parts of mandolins, and frames and horns of talking machines are often of beech.

It is listed among woods available for weaving and knitting machines, particularly for certain styles of shuttles and spools, and for bobbins in lace-making machines, crochet hooks employed in handwork, and in darning machines. The pairs of concentric hoops for stretching fabric to be embroidered are often of beech, the wood's strength and stiffness making it possible to have such hoops very thin and narrow.

Larger machines and appliances also find this strong, smooth wood valuable. Carpenters' workbenches are frequently made of it, but more particularly the bench screws turned from solid pieces. This tool must stand trying service, and there are not many woods, especially those of moderate cost, that will endure the strain. Other articles for which beech has proved its value are factory trucks, pulley blocks, and parts of weighing machines.

Printers and bookbinders use much machinery, many tools, and various kinds of cabinets and furniture made of wood, and beech, next to sugar maple, is most often employed. Type cabinets and rule cases, as well as the ordinary type cases and case racks, are frequently made of beech. The list of other articles for printers and bookbinders in the construction of which beech is a favorite material includes ruling machines, sewing frames, clamps, galleys, mallets, quoins, sort racks, and wooden type.

Beech is an important handle wood, though not in the same class with hickory. It is not selected because of toughness and resiliency, as hickory is, and generally goes into plane, handsaw, pail, chisel, bundle, and flatiron handles.

Woods lighter than beech are preferred for the sides of ladders, but beech is frequently taken for rungs and steps. In the manufacture of step chairs—a kind of low ladder—beech is sometimes the only material used.

The manufacture of wooden shoes in the United States has reached considerable proportions. Several factories make them, and a number of woods are employed. The two principal qualities insisted upon are lightness and imperviousness to water. Beech lacks lightness, but it so admirably meets the second requirement that it supplies much of the wooden-shoe material. A pair costs from 60 to 75 cents, and is good for two years' wear in cold or wet places, such as tanneries, bakeries, livery stables, street cars, breweries, and laundries. They are also used by farmers. Sometimes the soles only are wood, the uppers being leather or felt. Shoes of this kind are intended for steel mills and glass factories where the workman must walk on hot grates and floors.

Saddle trees, whip handles, trunk slats, boat oars, and mine rollers are among articles made of beech because the wood is stiff, strong, and cheap. It is listed as shoe-last material, but an examination of statistics of output from many last factories shows that its use for this purpose is very small.

The hardness of beech early recommended it for paving blocks, but untreated material proved unsatisfactory because of its speedy decay.

In 1909 the pulp mills of the United States bought 31,300 cords of beech. Several other woods rank above it in quantity, but its place is not unimportant.

Statistics for 1909 show that in the production of slack-cooperage staves, only two woods, red gum and pine, stood above beech in quantity, while for heading, pine alone exceeded it.

PRESERVATIVE TREATMENT.

In 1909 the railroads of the United States bought 195,000 beech ties. Statistics do not show how many of these were treated with preservatives to check decay, but many of them were, for in an untreated state the wood lasts only a short time when laid in tracks. Beech mine timbers are often given treatment, otherwise their life in the damp, spore-laden air of underground galleries is short. If it is to be employed in damp situations, effective treatment lengthens this wood's period of usefulness three or four fold. Its hardness qualifies it for

long service as paving blocks, if properly treated with preservatives. Some of its most promising future uses may reasonably be looked for through the aid of preservative treatment.

DISTILLATION.

The most valuable by-products of beech are obtained by distillation. Mention has been made of early beech charcoal. Methods much more effective and less wasteful are now employed in making this commodity, and a number of additional products are now extracted. Destructive distillation is to-day carried on with great success in large and costly plants. Beech, of course, is not the only wood put through the process, but it is one of the most important hardwoods, the others being birch and maple. In 1909, in the United States, 1,149,847 cords of hardwood were distilled. The kinds and quantities of the products were:

Charcoal	bushels	53,075,102
Crude alcohol	gallons	4,468,083
Gray acetate	pounds	148,769,479
Brown acetate	do	2,156,907
Iron acetate	gallons	302,624
Oils	do	37,995

An average cord of wood by this process of distillation yields:

Charcoal	bushels	46.16
Crude alcohol	gallons	7.37
Gray acetate	pounds	129.39
Brown acetate	do	1.88
Iron acetate	quart	1
Oil	gill	1

The average cost of a cord of wood was $3.32, and the value of the product extracted was $6.65.[1]

These products enter into many arts and trades. Charcoal is used as fuel for home, bakery, and shop, and in blast furnaces, in the manufacture of gunpowder, and for filtration in sugar refineries. Wood alcohol is a fuel, but its principal use is as a solvent in making varnishes and shellacs and in the manufacture of perfumery, dyes, and commodities of a similar kind. The acetates are valuable for making wood vinegar, acetic acid, ether, and acetone.

BY-PRODUCTS.

Beech wood is considered best for the manufacture of pharmacopœial creosote, employed in medicines for pulmonary diseases. This creosote is not poisonous as coal-tar creosote is. The laws of Austria require that pharmacopœial creosote shall be manufactured from no wood but beech. The bark of beech is employed in tanning in Europe, but is so used little or not at all in this country. Oil made

[1] These figures are based on statistics given in "Forest Products of the United States, 1909," pp. 163–167, compiled by the U. S. Census in cooperation with the Forest Service.

from beechnuts is substituted for olive oil in Europe, and the kernels are ground for flour and eaten after the oil is extracted. This suggests a possible use for the nuts in this country. They are occasionally gathered and sold in Canada and in some of the Northern States, but the trade is not large.

SWEET BIRCH.

(*Betula lenta.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—47.47 pounds per cubic foot (Sargent).

Specific gravity.—0.7617 (Sargent).

Ash.—0.26 per cent of weight of dry wood (Sargent).

Fuel value.—102 per cent of that of white oak (Sargent).

Breaking strength (modulus of rupture).—17,000 pounds per square inch, or 136 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—2,042,000 pounds per square inch, or 152 per cent that of white oak (Sargent).

Wood heavy, very strong and hard, compact, satiny, susceptible of a beautiful polish; medullary rays numerous, obscure; color dark drown, tinged with red, the sapwood light brown or yellow. The peculiar luster of this wood, when well polished, is due to the bright lining of the wood pores.

Height, 55 to 90 feet; diameter, 1½ to 4 feet.

SUPPLY.

Sweet birch is found in commercial quantities in half of the States, its range lying chiefly east of the Mississippi River, but crossing a little into Minnesota. No cut is reported from Mississippi, Alabama, Louisiana, or Illinois, but it comes from all other States in the eastern half of the country. The wood is lumbered in rather small amounts compared with some of the oaks and pines, but is of much importance because of its excellent qualities. Exact statistics of output are not available because this birch has been grouped with several others in Government reports of lumber operations. The birch sawmill cut in 1909 was 452,000,000 feet, but this included, in addition to sweet birch, yellow birch (*Betula lutea*), gray birch (*Betula populifolia*), paper birch (*Betula papyrifera*), river birch (*Betula nigra*), and perhaps some of the less abundant species.

The sweet birch on the market comes from several widely separated regions. Nowhere does it form extensive stands. The trees are cut as lumbermen come to them in logging operations among other species, and few if any mills saw birch exclusively. Though it is not known what amount of sweet birch still remains, it is probably much under that of beech, and certainly less than sugar maple. In 1908 a reconnaissance of the standing timber in Kentucky credited that State with 55,000,000 feet of birch, but yellow was included with the sweet. Michigan has been a leader in the

production of this wood for years, and some well-informed timbermen in the State believe there is not 15 years' supply at the present rate of cutting. Wisconsin now leads in the production of birch lumber, but most of it is yellow birch.

The supply of sweet birch in the forests has been diminishing steadily since the settlement of the country began, especially in the valleys and coves among the mountains where the best of the birch has always been found. The narrow and fertile tracts between ranges of hills made good farms and were early cleared. The finest birch went into log heaps and was consumed to make way for pasture and grain. The pioneer's wide fireplace demanded large quantities of fuel, and the splendid birches of the near-by coves were felled and converted into firewood. This process went on from Tennessee to Maine for a century or two, and had destroyed the finest of the country's birch before the value of the wood for lumber was realized. During the past 30 or 40 years sawmills have been putting it on the market, and are now rapidly cutting out the remnants of the splendid but scattered birch forests.

The most difficult problem which the early sawmill man had to solve was to prevent birch lumber from warping. Few woods behave worse when attempts are made to season it in the old way. The only process known by the rural millman years ago was to pile his birch and upon it stack thousands of feet of other lumber. If he succeeded in superimposing weight sufficient to hold the birch straight it slowly seasoned and gave no further trouble. Modern mills using improved methods, have no especial difficulty in seasoning birch.

EARLY USES.

Though in early times sweet birch was used chiefly for fuel, there is evidence that it was on the market as timber more than a century ago. As early as 1791 shipments were going regularly to Clyde and Liverpool.[1] The use to which it was put in England and Scotland is not stated, but at or about that time it was found in New England shipyards. It is stiff and strong, and was suitable for many parts of vessels, if placed where it was not subject to alternate dryness and dampness. In unfavorable situations it is not durable. Small-dimension stock cut from green logs gives much trouble because of its tendency to warp, but large timbers behave better.

Birch is believed to have been the first wood employed as an imitation of mahogany in this country, but the exact date is uncertain. Boston furniture makers were putting it to that service very early. It is still so used, and one of its commercial names is mahogany birch, given it because of its success as a counterfeit. It is called

[1] "Commerce of Europe," p. 542, J. J. Oddy, London, 1805.

mountain mahogany for the same reason.[1] Cherry birch is another of its names, due to its success as a substitute for cherry. It is sometimes called red birch and white birch, the first name bestowed because the heartwood is red, and the second because the sapwood is white. Some designate it as river birch, which is apt to lead to confusion, because that is the proper name of a different species (*Betula nigra*).

While Boston was staining birch and selling it as mahogany in furniture and musical instruments, New York carriage makers were building fine panels of it and finding ready sale for their product without hiding it under false names. There was more temptation from a money point of view a hundred or more years ago to substitute birch for mahogany than there is now. Mahogany was about as expensive in this country then as it is at present, while birch was not half as costly as now. The artistic front of many a chest of drawers passed for mahogany a century ago (and may still pass as such in antique collections), though the wood grew in Massachusetts, New York, or Pennsylvania.

Birch is named in old lists of shoe-last material, but it appears to have passed out of service in that capacity.

FURNITURE.

Among the earliest recorded attempts to make high-grade furniture of sweet birch were those successfully carried out at Boston. Hand-carved arms for chairs were turned out in attractive designs. The early hand processes expanded and developed into manufacturing as the term is now understood. Sweet birch, being a wood of high grade, has been prominent in furniture manufacture from the first successful attempts. It is physically equal to nearly any wood; it is heavy, dense, of good milling qualities, lends itself to stains and fillers, and holds finish well. There is probably no important line of furniture produced in this country which does not make use of some birch. The earliest furniture of this wood seems to have been chairs, and at this day chairs are of sufficient importance to claim first place. The range rises from the cheap camp chair or stool to the finest rocker. The entire article is not necessarily birch; in fact, it seldom is. This wood may supply only the back, the seat, the arms, the rockers, or some of the slats, rounds, or spindles. A special place for it is found in opera chairs, in which three or five ply veneer, the visible wood being birch, is shaped for seats and backs. School desks in large numbers are manufactured in similar patterns. Morris chairs, of which the arms at least are of this wood, are widely sold,

[1] The mountain mahogany of the Rocky Mountains and the Sierra Nevada is a different wood (*Cercocarpus ledifolius*).

and a still higher grade is found in upholstered and plain parlor suits, including davenports, sofas, settees, squabs, and lounges. The heavier of these articles are on casters, which are often of birch, as its hardness and strength fit it for such service.

Several important places in church furniture and fittings are admirably filled by sweet birch, although it is not so extensively employed as oak. It is made into pews, pulpits, communion tables, contribution plates, pulpit chairs, and Bible stands.

It is a popular cabinet wood and enters into the construction of a long list of articles, from kitchen tables and cupboards to elastic bookcases and filing cabinets. It is not always the outside wood, but usually is, especially the richly colored heartwood. It should be borne in mind that there are two kinds of sweet birch, as the cabinetmaker views it—heartwood and sapwood. The difference in color is apparent at a glance, and the workman selects his material for the sake of color. He selects it as carefully for another reason, if he employs glue to fasten the parts together. Birch does not nail readily, because of its tendency to split, and much of it is either dovetailed or glued. If it is glued the best results are attained only when sapwood is glued to sapwood and heartwood to heartwood. Birch appears in many kinds of desks, not only as an imitation of cherry or mahogany but on its own merit. Smoking stands and card tables of this wood are also popular. Children's cribs, folding beds, china closets, extension tables, wall cases, hall trees, taborets, umbrella stands, chiffoniers, and dressers of sweet birch are listed by many factories.

MUSICAL INSTRUMENTS.

Its beauty, strength, and rigidity have made sweet birch prominent as a material in the manufacture of musical instruments. Its beauty, however, is considered oftener than its other properties, for it is usually the outside wood. In some cases, however, its other properties commend it, such as for piano hammers, framework of pianos and piano players, and pipes for organs. Almost every kind of musical instrument in which wood is used has drawn upon sweet birch for material. Special mention might be made of guitars, mandolins, banjos, and violins. Such instruments show the wood most frequently in the necks, although the mandolin is often made of birch and some lighter-colored wood in alternate strips. Drum makers bend a broad, thin band of birch for the shell of this instrument, and in harps it is often the frame, and chosen for its rigidity. In orchestrions or large music boxes, and when employed for cases of pianos and piano players, and for organ cases and musical cabinets, its appearance is the chief consideration. Piano stools and benches are articles in which the fine qualities of well-selected birch are seen to advantage.

VEHICLES.

In its importance as a vehicle wood, sweet birch ranks much below the hickories and some of the oaks, but it fills a number of places. It is well suited for panels, sometimes solid and sometimes of built-up veneers, which find place in fine carriage and automobile bodies. Passenger and sleeping car builders also use birch for paneling. Automobile manufacturers have found several places for sweet birch. It goes into seat frames, floors, filler boards, dashboards, tops, dashboard frames, and steering wheels. It fills some of these places because it is strong and stiff; others because it is handsome. In either case only the highest grade is employed. Some sweet birch is made into hubs, but it is not in the same class as elm and oak for this purpose. It is sometimes seen in the hubs of light carts and buggies. For children's sleds and wagons birch is one of the available woods.

FLOORING AND FINISH.

Sweet birch is a satisfactory wood for flooring, whether the purpose is ornament or long service or both. The wood is handsome, it stands well when thoroughly seasoned, and it lasts a long time. Large quantities of this flooring are made in the Lake States and it finds service in houses of the better class in practically all of the Eastern and some of the Western States. A smaller amount is manufactured into parquet floors and into wood carpet. The dark heartwood is much valued for the last-named commodities, because it forms pleasing contrasts with woods of lighter color.

Ornamental columns of sweet birch find place indoors. Newel posts of the same wood and the associated rails, spindles, and steps of stairways belong in the same class, along with brackets, capitals, chairboards, moldings, grills, and mantels. Window frames, door frames, and blinds of birch are exquisite finish when a dark, rich effect is desired. Birch doors are a special article—that is, particular pains are taken to finish them in the most attractive style, after selecting choice material. Curly birch is often seen to best advantage in this class of work. The wavy grains and figures are matched in the panels, stiles, rails, and mullions. The curly wood is frequently cut into veneer for the double purpose of making it go farther and securing better seasoning. It is not uncommon to equip birch doors with knobs of the same wood. Many birch knobs, however, are used elsewhere than on doors; furniture makers find many places for them. Ceiling is little less important than flooring in the quantity of birch used. A considerable amount of the birch ceiling listed is intended for porches. The wood shows to good advantage in wainscoting, where the dark wood of the heart is sometimes alternated with a white wood such as maple. Floors and ceilings are often made in the same way.

ARTICLES FOR AMUSEMENTS.

A long list of articles for games and amusements are partly or altogether of wood, and sweet birch supplies a liberal share of the material for their construction. Billiard tables are the largest and most costly. Not only does birch enter into the making of the tables, usually as the outside in the form of veneer, but racks for cues and balls, and the cues themselves are often of this wood. The stock of the cue is made attractive by building it up of different colored woods, turned to proper form and highly polished. The makers of bagatelle tables report birch as one of the high-grade woods employed. It is demanded by the manufacturers of a long line of goods found in gymnasiums, including dumb-bells, Indian clubs, and pitch-and-ring. Croquet mallets and balls are on the list also, as are checkerboards, tennis rackets, and numerous toys, particularly building blocks, puzzle blocks, children's games, and wooden guns.

MISCELLANEOUS.

Manufacturers of artists' material use much of the dark heartwood of sweet birch, either in its natural finish or in imitation of mahogany and cherry. The articles in which the wood is found acceptable are easels, maulsticks, rules, palettes, paint boxes, and panels for painting.

Boat builders, who were among the earliest artisans in the country to employ birch, are still rather large users of the wood. It is one of the best for canoe decking and for decking, railing, and finish of motor boats. It frequently passes for mahogany, but some boat makers advertise the fact that they trim with birch. Steering wheels of this wood are very handsome and are to be seen on automobiles, motor boats, and on vessels of larger size.

Much good birch is manufactured into broom handles, though beech exceeds it in quantity. Its dark color is by some regarded as objectionable, and the cost of the wood is also against its employment for handle making. In the manufacture of carpet sweepers, however, birch makes up what it loses in the broom-handle shop. The backs and handles of hair brushes and clothes brushes call for some of the most select sweet birch. It is there in the same class with mahogany, ebony, rosewood, and callitris.

The makers of electrical apparatus need a comparatively small amount of wood, but the quality must be good. Sweet birch is well up in the list and finds place in switchboards, bases for telegraph instruments, telephone boxes, and tables.

It is too costly a wood to be profitably used for ordinary crating and packing boxes, but there are both high and low grades of birch, the latter consisting chiefly of sapwood and pieces too knotty for first-class commodities. This cheap material swells the supply of box lumber, and a little of it is found wherever birch passes through

sawmills. The most frequent objections against sweet birch as box lumber and crating material are that it is hard to nail and is inclined to split.

Apple wood, beech, and sweet birch are important woods for handsaw and plane handles.

It is demanded by manufacturers for tackle blocks, for carpenters' and sheet-metal workers' benches, and for frames for boring machines. In the manufacture of agricultural implements it has a wide range of uses, serving as frames, braces, chutes, hoppers, pitmans, seats, seed boxes, and in numerous other places where strong, stiff, and serviceable wood is wanted.

It is popular for picture frames where a dark wood is desired, and it gives wide service when made into molding for interior finish and decoration. Trunk and suit-case makers manufacture it into slats and veneer, the latter in thicknesses of three or more ply. Another place where it gives good service is for canes and umbrella handles. The same wood is often preferred for blue-print frames and is specially well liked for frames of large cameras. It is seen in tripods, and it is also made into parts of surveyors' and draftsmen's instruments and tools.

Slack coopers press this wood into service with many others, and it goes to market as barrels and kegs. It is given a little better place by woodenware manufacturers, who make tubs and kits of it which are not meant to be thrown away when once used. It appears also in commodities of another class—thin platters of veneer, picnic plates, and butter dishes. Sweet birch, however, is not so well liked for these articles as are yellow and paper birch, maple, and beech.

Fixtures for offices, stores, banks, bars, and hotels require many high-grade woods, and sweet birch is in the list with walnut, cedar, mahogany, oak, cherry, and others. Among the places in which birch is found are counter and bar tops, standing desks for bookkeepers, partitions, cabinets for drugs or other merchandise, show cases, display tables and racks, shelves, and grille work, cold-storage rooms, refrigerators, and soda fountains.

An increasing demand for sweet birch comes from makers of coffins and caskets. Perhaps it is oftener displayed as mahogany than under its own name.

DISTILLATION.

Sweet birch is one of the most important woods which contribute to the hardwood distillation industry described in this bulletin under beech. This process is important because it turns waste into profit, and utilizes portions of trees and mill refuse which otherwise would be lost.

BY-PRODUCTS.

Several by-products are derived from sweet birch. For 200 years white men have made birch beer, and Indians have made it from time immemorial. It is considered a harmless beverage, and is seldom a commercial commodity, but is pretty generally made within the sweet birch's range. The flow of sap from this tree is much more copious than from the sugar maple.

In early summer the soft layer of new wood just beneath the bark is edible. The taste is peculiar and pleasant. It can not be classed as an important article of food, but trees are often peeled to obtain it.[1]

It is said that the characteristic odor of Russian leather is due to birch oil obtained in America and employed in dressing the product.

The commercial oil of wintergreen is frequently made of sweet birch. It is not an article of much value from a commercial standpoint, but it is one of considerable interest. About the year 1863 in Luzerne County, Pa., a trade in the genuine oil of wintergreen (*Gaultheria procumbens*) came into existence. It was presently discovered that sweet birch, by distillation, yielded an oil so nearly like that of wintergreen that only by painstaking chemical analysis could the counterfeit be detected. At first, birch and wintergreen were distilled together in the same vessel, but birch was more easily procured, and it gradually displaced the wintergreen. The industry has continued to the present time in mountainous regions of Pennsylvania, West Virginia, Kentucky, and North Carolina, but it has always been carried on after the simplest and most primitive fashion. A ton of chips yields only 2 quarts of oil, which is used to flavor candy and medicines. The oil consists largely of salicylic acid and wood alcohol. It is not unusual for the mountaineers to sacrifice 100 or more young birches to make a pint of oil.

The supply of sweet-birch lumber must decline, for the tree does not grow rapidly, and the best wood is not produced on the rugged mountain sides where the future supply must be sought. The species has not yet appealed to those who are planting for commercial purposes, and if planted a long time will be required for trees to grow large enough to develop the richly colored heart which gives this wood its chief value.

YELLOW BIRCH.

(*Betula lutea.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—40.84 pounds per cubic foot (Sargent).

Specific gravity.—0.6553 (Sargent).

[1] At the battle of Carricks Ford, W. Va., in 1861, a portion of the Confederate army, under Gen. Robert S. Garnett, was cut off and driven into uninhabited mountains. Sweet-birch bark is said to have saved the lives of hundreds of soldiers. They subsisted upon it several days while making their way over the mountains to Monterey. Years afterwards their line of retreat could be traced by observing the peeled trunks of birch trees.

Ash.—0.31 per cent of weight of dry wood (Sargent).

Fuel value.—88 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—17,000 pounds per square inch, or 138 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—2,478,000 pounds per square inch, or 188 per cent that of white oak (Sargent).

Heavy, very hard and strong, compact, satiny, susceptible of a beautiful polish, medullary rays numerous, obscure; color light-brown, tinged with red, the sapwood nearly white.

Height, 60 to 80 feet; diameter, 1½ to 3 feet.

SUPPLY.

The range of yellow birch extends from eastern Maine to northern Minnesota and southward to Tennessee and North Carolina along the Appalachian ranges. It is a northern tree and reaches its best development near the Canadian border. It is known also as gray, silver, and swamp birch. Its names are all descriptive, but swamp birch may mislead, as it does not grow well in deep, cold swamps, though it is often found around their margins. The young tree is silver white, but as it increases in size the bark takes on a yellow tinge. The wood is not yellow, but the sapwood is white and the heartwood brown, or often reddish.

Within its range the species is fairly abundant, and in the past it has easily met all demands made upon it. It is not probable, however, that it will continue abundant, for it is being rapidly cut, and the changing forest conditions in logged regions are not conducive to new growth of this species. It is, besides, a very slow-growing tree, and a century is required to produce a trunk large enough for small saw timber. It is an abundant seeder, and it disperses its seeds well; but their natural germinating bed is the ground of an old forest with plenty of shade and moss. Old moss-covered logs and rocks buried in moss are favorite sprouting places for the seeds of yellow birch. The roots grow into the ground, and when the log decays the tree is left standing high on its proplike roots. Occasionally a tree stands above a bare rock, with roots down the sides to the ground, presenting the appearance of having grown from a seed which germinated on a naked rock. Forest-grown yellow birches develop tall, clean trunks with small crowns, splendid sticks for lumbering. When grown in the open, however, they are limby. They push vigorously into vacant ground that has been opened by windfalls or fire and also into abandoned fields, and in such situations are often able to hold their place. Few yellow-birch forests of considerable extent, however, are coming on, and the species can not contribute much to the lumber supply after the present stand is cut.

EARLY USES.

Early records showing the use of yellow birch are comparatively few. It was not a wood to attract much attention when forests were

unbroken and many fine species abundant. For that reason it is somewhat surprising that as long ago as 1803 it was listed at Pittsburgh as a furniture material and contributed, together with black walnut and cherry, to the trade in furniture with settlers embarking there for Kentucky, Ohio, Indiana, Illinois, and Missouri.

Before 1803 yellow birch was giving service in Maine, though the amount demanded must have been small. In some instances it was used in ways rather peculiar. The long, slender saplings were cut for withes, which were employed in binding furs and household goods for shipment, for baling hay, and even in binding coffins, though what useful purpose was served in the last case early chronicles do not state. Bent-wood yellow-birch cradles for children were common.

Textile mills came into New England at an early day, and their demand for bobbins and spools was met in part by yellow birch, though it was of less importance for such uses than its forest neighbor, paper birch. Yellow birch is to-day one of the regular woods demanded for spools and bobbins in New England mills, and this service is probably its most important one outside of its use for furniture.

FURNITURE.

Yellow birch is not usually considered equal to sweet birch as a furniture wood, but it is much used, and not infrequently the purchaser of birch furniture buys the yellow without knowing the difference. The better grades of the heartwood are so much like the heartwood of sweet birch that only persons well acquainted with both can distinguish one from the other. When finished naturally—that is, when the grain of the wood is not concealed or doctored by stains—the sweet birch possesses a softened characteristic glow which yellow birch never shows. Yellow birch lends itself well to the finisher's art, and much handsome furniture, strong and substantial, is made of it. The largest use is probably in the Lake States.

In the manufacture of bookcases, chiffoniers, dressers, tables, wardrobes, commodes, couches, lounges, settees, and other household furniture the visible wood, if of birch, is the heartwood, selected for its color, while the sapwood, which is yellow or white and without attractive grain, goes to inside parts, such as drawers, partitions, slides, and backing for veneer. In lessening sawmill and shop waste, a good deal of the strong and stiff sapwood must be worked into something not intended for show, and the manufacturer of furniture has many places where such material can be employed. In cheaper kinds of furniture, like kitchen tables and cabinets, the sapwood can be used for outside parts. It is really more desirable than the heartwood in such places, because it is white and is easily kept clean.

Some makers of morris chairs and large rocking chairs employ much yellow birch, as it is well suited to articles where weight,

strength, and stiffness are desired. It is a good dowel wood because it is strong.

Makers of office furniture draw upon yellow birch for both outside and inside wood. The principal articles into which it goes are desks, large tables and small stands, chairs, benches, and filing cabinets containing numerous drawers and compartments, as well as fixtures for offices, banks, stores, and bars.

VEHICLES.

Yellow birch has not as wide or important a place in vehicle making as have some other woods, but it is well fitted for certain uses because it is hard, strong, and stiff. Its cheapness is often a controlling factor in its use. It has long had a place in hub factories, particularly for small vehicles. The hub is made in a single piece turned down to proper size and shape. In Maine logs down to a diameter of 9 inches are received in the hub factories. The manufacturers of automobiles find it suitable for filler boards and for parts of frames. Factories making gocarts and carriages for children buy yellow birch in considerable quantities and use it for frames, bottoms, and handles. Stone boats, which are strong, heavy, and clumsy sleds for dragging stones short distances, are frequently made of yellow birch. There is a long list of places in general vehicle making where it serves occasionally.

WOODENWARE.

Yellow birch finds a place in practically all kinds of woodenware. A large percentage of the birch broom handles on the market are of this wood, though nearly every other birch contributes something.

It goes into the thin plates and dishes made for pies, butter, lard, and many other commodities, though the quantity used falls much below that of maple and beech. The large number of yellow birch logs in the yards of factories making such plates show, however, that the wood is extensively employed. Statistics of finished products turned out by the industry give little information of species used, the custom being to class everything as "hardwood."

Tubs and pails are sometimes made of yellow birch, provided weight is not objectionable. The wood is twice as heavy as some of the pines and cedars. It does not seem to be specially sought after by this class of coopers, but is employed because it is cheap, convenient, and good enough.

Many small handles for such articles as flatirons, gimlets, augers, screw drivers, chisels, varnish and paint brushes, and butcher and carving knives are made of the wood, some of sapwood, others of heart.

A long list of novelties draw upon yellow birch, including many kinds of small boxes and kegs in two pieces, such as pill boxes, and boxes of soap, toilet powders, medicines, tacks, paper fasteners, school supplies, and other articles almost without number.

MISCELLANEOUS.

The miscellaneous uses of yellow birch range from workbenches and grain doors down to toothpicks. It is not the exclusive material for any of the many commodities into which it is converted, but holds an important place as a contributor. The textile mills make spools and bobbins of it, but paper birch is better. Brush manufacturers find many places for it, but sweet birch and sometimes the heartwood of paper birch are preferred. It goes into millions of toothpicks, but is not generally liked as well as the white paper birch. It is widely utilized for shipping boxes, baskets, and crates, and it is one of the stiffest, strongest woods procurable, but on account of its excessive weight it is sometimes discriminated against. It is excellent for veneer boxes, and that is probably one of the most important places it fills. Citrus fruit from northern Africa and the islands and countries of the Mediterranean is often sent to market in boxes of yellow birch, made from veneer cut in New England. Skewers from this tree are in many markets, but those of hickory are usually preferred, because they show less tendency to split and splinter. Button molds and the wooden body of tassels are frequently cut from yellow birch. Soap sticks draw from the same source of supply. Carefully selected heartwood finds many places in interior finish, such as newel posts, stair rails, chair and baseboards, spindles, brackets, and sometimes panels, partitions, and ceilings. Much of it is unselected for color, since uniform effects in almost any stain can be obtained with both heartwood and capwood.

Other uses for yellow birch are in the manufacture of artists' materials, palettes, easels, rules, and stretchers; tradesmen's triangles and squares, dumb-bells and Indian clubs for the gymnasium; puzzles and toy blocks for children, and novelties of many kinds.

DISTILLATION.

The products of distillation from yellow birch are the same as from beech, for the woods go to the chemical plants together.

Oil of yellow birch is sometimes employed to flavor candy and soda water.

PAPER BIRCH.

(*Betula papyrifera.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—37.11 pounds per cubic foot (Sargent).
Specific gravity.—0.5955 (Sargent).
Ash.—0.25 per cent of weight of dry wood (Sargent).

Fuel value.—80 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—14,900 pounds per square inch, or 119 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—1,841,000 pounds per square inch, or 139 per cent that of white oak (Sargent).

Light, strong, hard, tough, compact; medullary rays numerous, obscure, color brown, tinged with red; the sapwood nearly white.

Height, 50 to 70 feet; diameter, 6 inches to 3 feet.

RANGE AND SUPPLY.

The range of paper birch includes the northern tier of States almost from ocean to ocean, extending into New York, Pennsylvania, Illinois, and Nebraska, and northward almost to the Arctic Ocean. Few trees of this country have a more extensive range, but it is not everywhere of commercial importance. The tree is short-lived, and the trunk is often defective. At best, it is not an ideal timber tree and in some regions where its size is fairly satisfactory lumbermen are inclined to pass it by because of decay. It endures cold, but unfavorable climatic and soil conditions stunt the tree. On Mount Washington, in New Hampshire, at an elevation of 5,700 feet, paper birch is a prostrate shrub. It assumes a similar form near the northern limit of its range in British America; but in other parts of its habitat much good timber is found. The best appears to be in New England, where the annual cut exceeds 30,000,000 feet. In Maine it is rated second in stand among the hardwoods, while farther west, in Michigan, Wisconsin, and Minnesota, it is often mixed with softwoods, such as white and Norway pine, balsam, fir, spruce, northern white cedar, and tamarack. Frequently, however, it grows in pure or nearly pure stands.

It is known as paper birch, canoe birch, white birch, silver birch, and large white birch. It is not readily mistaken for any other tree with which it associates, for the tendency of its bark to roll up in bands around the trunk is a noticeable characteristic. Several birches shed their old bark in strips, but in almost all cases each species has some feature which distinguishes it from paper birch.

It is one of the few American species with a hold on the forest stronger than it had when America was discovered. Large tracts are now covered with this birch where there was little of it a century ago. It is remarkably successful as a fire tree, one that pushes in and occupies vacant spaces left by large forest fires. Some tracts thus taken possession of within a century, or half a century, cover hundreds of square miles. This birch is a prolific seeder, and the light seeds are carried far by wind. When they fall on bare mineral soil, free from shade, they spring up and grow vigorously. Paper birch, however, is short-lived, and when some of the weaker trees begin to fall other broadleaf species get a foothold, and finally the birch is

crowded out. Thus a disastrous fire allows the birch to possess and hold the ground for a time, but it is not strong enough to maintain its position when competition becomes keen. This characteristic must be taken account of when figuring on birch supplies in the future. It has been estimated that enough is in sight to meet visible demands for about 40 years, especially in the northeast, but predictions beyond that period are not made by careful students of the tree's habits and history. Some of the best stands of paper birch in the northeast are in areas denuded by great fires which visited the region from 1825 to 1837. It grows rapidly during its first years, but more slowly afterwards, reaching maturity in from 50 to 85 years.[1]

CANOES.

Paper birch is widely known as canoe birch, because its bark was once employed in making those light vessels. The original makers were northern Indians, and there is no history or tradition when they were not using vessels of that material to navigate the rivers and lakes of northeastern United States and half of British America.[2] It would be difficult to estimate the value of the service of the bark canoe in the discovery, exploration, development, and settlement of the northern part of the continent. From the Arctic Circle to the Great Lakes, for a century and a half, that light but exceedingly strong and serviceable vessel threaded the lakes and rivers, bearing trade and carrying civilization where no other boat could go. The bark canoe was so light that the crew it carried on water could carry it over land from one river to another and from lake to lake, even where mountains lay between. The French explorers and missionairies made journeys of hundreds of miles in these canoes, carrying in many instances cargoes which seem beyond the capacity of such frail vessels. Long distances were traversed in what seems remarkably short time. It is recorded that the first fleet of bark canoes carrying white men reached Sault Ste. Marie, Mich., in 1641, after a journey of only 17 days from the Ottawa River.[3]

The bark of the paper birch seems to meet every requirement for canoe making. It is light, tough, strong, pliable, and resists decay in a remarkable manner. It is not taken from the trunk in single

[1] U. S. Forest Service Circular 163, pp. 10, 11, and 21.

[2] In Longefellow's poem "Hiawatha" may be found a description of the making of the first birch-bark canoe. The account is mythical, but the description of the process of making it is accurate.

[3] There is perhaps no single book that will give more first-hand information concerning the actual use and importance of the birch-bark canoe, when it was employed in the serious business of life, than the journals of Sir Alexander Mackenzie in Voyage from Montreal to the Pacific Ocean, published in London, 1801. The value of the forest resources to the explorer and traveler is admirably shown in the diary of that remarkable Scotch pioneer, who was perhaps the first man to cross the Rocky Mountains with a canoe, which he carried when it would not carry him.

pieces large enough for a canoe (as is done with Sitka spruce on the northern Pacific coast), but in sections 4 or 5 feet long up and down the trunk and as wide as the circumference of the tree.[1] A bark canoe was very strong, and yet so yielding in all its parts that it would stand shocks and blows which would immediately destroy a small boat made of wood or metal.[2]

The birch canoe was not always made for long service. Sometimes it was intended as a temporary makeshift, and in that case the bark was stripped from the trunk in a section 10 or 15 feet long, the ends were rolled up and tied to keep out the water, a few sticks were inserted as cross braces, and the vessel was ready for the slight service expected of it.[3]

The birch-bark canoe was never made and was seldom seen south of the tree's natural range, that is, New England and part of New York, and westward near the Canadian border. The bark canoe is to-day occasionally seen on the northern lakes and rivers, usually at summer resorts.

SHOE PEGS AND SHANKS.

It is commonly thought that shoe pegs have nearly passed out of use, but statistics of the manufacture of the article do not warrant that belief. Eleven thousand cords of paper birch are made into pegs and shanks yearly in New England. A small quantity of other woods is used also. Shanks are small, flat pieces of wood inserted between the soles under the arch of the foot. Joseph Walker, of Massachusetts, perfected his machine for the manufacture of pegs about 1818. It is not apparent that the "invention" of pegs marked the beginning of their use, for it is claimed that handmade pegs were well known before the introduction of Walker's machine.

Two methods of manufacture are now employed in making pegs: One cuts the bolt into blocks of requisite length, and splits out the pegs; the other cuts sheets of rotary veneer the thickness of a peg, and then splits and points them. The waste is large, for though a shoe peg is about the smallest commodity manufactured of wood, it can not be made of small pieces and scraps. The chief waste is due to the rejection of entire defective logs and the heartwood of all others.

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[1] The bark canoes used for carrying merchandise in Canada a century or more ago were sometimes 48 feet long and 9 feet beam, and carried 8,000 pounds.—John Long's Travels, London, 1791, Reported in Early Western Travels, R. G. Thwaites.

[2] Alexander Mackenzie hunted whales with a bark canoe. The animals were found at the mouth of the Mackenzie River, having entered from the Arctic Ocean. He failed to strike the game and concluded that it was probably for the best, as he was doubtful if the canoe would have stood a blow from a whale's tail.

[3] "When they [the Indians] come to a river they presently patch up a canoe of birch bark, cross over in it, and leave it on the river's bank if they think they shall not want it; otherwise, they carry it along with them."—John Oldmaxon's British Empire in America, edited by Hermann Moll, London, 1708.

Shoe shanks are made from rotary veneer which is cut the requisite thickness, and are seasoned after they are cut out.

SPOOLS.

More than half the cut of paper birch in New England is manufactured into spools, the amount exceeding 40,000 cords a year. Nearly all thread spools, such as are used on sewing machines, are of this wood, and no other commodity demands so much paper birch. Two or three properties fit it admirably for spools. Its color is white and attractive, when seasoned it holds its shape, which is the most important thing for a spoolwood, for the least warping would make the winding of thread on it impossible with the delicate machinery employed for the purpose. Though the wood is fairly hard, its dull tools less than almost any other wood fit for spools. This is a valuable quality, for the lathe knives and bits must be kept very sharp or they will not cut true, and the spool will be spoiled. The wood easily takes polish, which is given the spools by rolling them about with balls of wax or paraffin in hollow cylinders.

The whole process of spool manufacture must be followed with care, beginning with felling the trees, which is done in New England in late fall or early winter. Logs 4 feet in length are cut and hauled to the sawmills as promptly as possible, the purpose being to give the wood no chance to stain. Defects due to growth or disease, such as large knots, pith, mildew, red heart, or stain, must be thrown out. The logs are sawed in bars of the required sizes. These, when properly seasoned, are cut into lengths and passed through lathes. A machine turns out a spool a second. The center of the spool industry in this country is in the Piscataquis and Penobscot Valleys in Maine, though there are mills elsewhere. The market for the product is at home and abroad. Scotland has long been a large consumer of paper-birch spool wood, but shipments to that country usually go in the form of bars, and not finished spools. The first shipment of bars to Scotland went from Bangor, Me., in 1882. The trade with that country is now decreasing because birch forests, recently made accessible in northern Europe, supply wood more cheaply.

The largest spools hold 12,000 yards, the smallest 20 yards. It is customary to manufacture the largest in three pieces, and sometimes two kinds of wood are employed, one for the ends and the other for the central shaft.

The rejection of so much wood by the spool manufacturer results in excessive waste. In some instances no attempt is made to use the waste for other purposes, but occasionally novelty mills are operated in connection with spool factories, and special attention is given to the utilitization of what the spool makers reject. In sawing small bars one-half of the log is cut away as sawdust, and this is seldom

put to any use. The red hearts are occasionally worked into brush backs, parts of furniture, or crating. If the slabs are not burned under the boilers they are frequently made into cordwood for fuel in towns and cities.

NOVELTIES.

The term "novelty" is difficult of exact definition, but when made of wood, novelties are generally understood to include miscellaneous small articles, both useful and ornamental. Large numbers of small wooden boxes are made by boring blocks of wood, shaping them in lathes, and fitting lids on them. Paper birch is one of the best woods for this class of commodities, because it can be worked thin, does not readily split, and is of pleasing color. Such boxes, or two-piece diminutive kegs, are used as containers for articles shipped and sold in small bulk, such as tacks, small nails, and brads. Such containers are generally cylindrical and of considerably greater depth than diameter. Many others of nearly similar form are made to contain ink bottles, bottles of perfumery, drugs and liquids, salves, lotions, and powders of many kinds. Many boxes of this pattern are used by manufacturers of pencils and crayons for packing and shipping their wares.

Such boxes are made in enormous numbers by machines. A single machine of the most improved pattern will turn out 1,400 an hour. After the boring and turning are done, the boxes are smoothed by "rattling" them in large cylinders with soapstone.

One-piece shallow trays or boxes, without lids, used as card receivers, pin receptacles, butter boxes, some kinds of fruit platters, and contribution plates in churches are often made of paper birch. When a more expensive wood is wanted, the choice falls on sweet birch, holly, black walnut, mahogany, and rosewood.

Paper-birch curtain rings are popular because they can be made so smooth that they slide readily upon the poles. Collar boxes of this wood, turned from solid pieces, are frequently seen, and wooden candlesticks are among paper-birch products coming from the lathe.

The line separating novelties from woodenware is obscure, but when this birch is employed in the manufacture of clothespins, clothes hangers, lamp mats, card racks, pail handles, and the like, the articles are generally classed with woodenware.

Large quantities of paper birch are made into toothpicks, about 3,000 cords annually in New England alone, which is much more than of all other woods combined. The highest grade is selected, and it must be free from red heart, knots, and other defects. It costs from $15 to $25 a cord. Toothpicks may, therefore, be regarded as the most exacting use to which paper birch is put. The wood is cut in rotary veneer, the length and thickness of the toothpick. This article is occasionally shipped to England, France, and Germany.

Paper birch is one of the many woods entering into the manufacture of door knobs, and it contributes also to button molds—the wooden interior pieces over which cloth or other covering is stretched to make covered buttons. Tassel molds are also made of the wood.

MISCELLANEOUS.

Some paper birch is cut for lumber in the Lake States, though it is not known how large the cut is, for it is listed with yellow and sweet birch without distinction. Much box lumber and crating are drawn from that source, and basket makers use it for fruit and berry shipping packages. The red heartwood—the part rejected by the spool and toothpick makers—is utilized to some extent in Michigan and Wisconsin for canoe decking, chair seats, and opera-chair backs. It contributes to interior finish and is turned for spindles, grilles, stair work, and balustrades. Candy sticks, for stirring candy in process of making, are one of the articles for which the white sapwood is in demand. The wood goes quite generally to excelsior mills in its range, and in Michigan a very fine grade, cut small, is called "wooden wool." This birch is reported in the manufacture of pulp, but the total quantity used can not be large. It is more important in the slack cooperage industry, and the quantity of staves, heading, and hoops made annually is rapidly increasing; but in this industry, as in many others, the several species of birch are not separately reported, and the exact proportion that paper birch supplies can not be determined.

BARK COMMODITIES.

The bark of the paper birch, made into canoes, gave the species great importance long before the wood was of any special value. The Indians put the bark to other uses. They manufactured considerable quantities of maple sugar in the North, and the ordinary storing vessels for their sugar were made of birch bark. Such boxes held from 20 to 70 pounds.

Early settlers made berry buckets and similar vessels by girdling the trees and stripping off the bark in rolls the size of a stovepipe or larger. The peeled, dead or dying trunks of paper-birch trees in many localities in the North are proof that the custom of making such buckets is not yet a thing of the past. Many trees are destroyed to secure the bark, of which only a small part—perhaps a section less than 2 feet long—is taken.

Stationery and other articles are made of paper-birch bark—envelopes, writing paper, visiting cards, programs, and even small books. Occasionally articles as large as tents are made of the bark. Formerly it was often so employed, and sometimes for the roofs of camps and cabins. The bark is the most enduring part of

the tree. Often a prostrate trunk is found in the woods which appears to be sound, but upon examination it is discovered there is little left but bark, the wood having rotted and wasted away.

Several species of birch occur in this country, which are of rather small commercial importance because of scarcity. Each one of them, however, is put to some local use.

GRAY BIRCH.

(*Betula populifolia.*)

Gray birch, known also as white birch, old-field birch, poverty birch, and poplar-leaf birch, is found in commercial quantities in New England and northern New York, where its most noticeable characteristic is its promptness in taking possession of abandoned fields. It is a short-lived, rather small tree, with light, soft, weak wood, which decays quickly when exposed to the weather. It is manufactured into spools, shoe pegs, barrel hoops, and wood pulp, and is often cut for fuel. It grows near the coast as far south as Delaware.

WESTERN BIRCH.

(*Betula occidentalis.*)

Western birch is one of the largest birches of this country, and is found in eastern Washington, Idaho, and Montana, but it is scarce and can not have much value as a commercial wood. Locally it sometimes serves for fencing, fuel, and rough ranch or farm timber.

KENAI BIRCH.

(*Betula kenaica.*)

Kenai birch is a small Alaska tree for which no uses have been reported except for fuel and other purposes about the camps of surveyors and prospectors.

WHITE BIRCH.

(*Betula alaskana.*)

White birch is an Alaska tree with a range extending eastward and southeastward across the Rocky Mountains to the valleys of the Saskatchewan and Mackenzie Rivers. It sometimes attains a height of 60 feet and a diameter of 18 inches, but it is usually smaller. It is abundant in some parts of its range, and when convenient to camps and settlements it is put to common local uses, but it has not been reported in the making of any commercial commodity. It is a most important fuel wood in interior Alaska. Its wood resembles paper birch.

MOUNTAIN BIRCH.

(*Betula fontinalis.*)

Mountain birch is small, and no use other than local has been reported for it, nor does it promise to become important in the future. It is a mountain species, as its name implies. It is found in localities from British Columbia to Colorado, and thence westward to the Sierra Nevada Mountains of central California.

RIVER BIRCH.

(*Betula nigra.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—35.91 pounds per cubic foot (Sargent).

Specific gravity.—0.5762 (Sargent).

Ash.—0.35 per cent weight of dry wood (Sargent).

Fuel value.—76 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—13,622 pounds per square inch, or 109 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—1,560,000 pounds per square inch, or 118 per cent that of white oak (Sargent).

Wood light, rather hard, strong, compact; medullary rays numerous, obscure; color brown, the sapwood much lighter.

Height, 50 to 80 feet; diameter, 18 to 30 inches. The species reaches its largest size in the far South, particularly in western Florida, Louisiana, and Texas.

SUPPLY.

No estimate of the quantity of river birch has been made. The species nowhere forms forests, but is found scattered along banks of rivers, margins of ponds, and in swamps where the land is above water most of the year. The tree will, however, do well on ground subject to rather long periods of overflow. Its range extends from Massachusetts to Florida, and westward to Texas, eastern Kansas, Iowa, and Minnesota. This area exceeds a million square miles, but the actual quantity of the timber can not be judged by the extreme outposts of its range, because over large districts it is not found and in others it is very limited. Among the names by which it is known in different regions are red birch, water birch, blue birch, and black birch.

River birch is one of the few American trees which ripen their seeds in the spring or early summer. The habit of this tree in growing along watercourses and passing uninjured through long periods of inundation suggests that water has much to do in the dispersal of the seeds. The tree, nevertheless, often grows entirely above the highest flood line. It is like the sycamore, in that the situation in which it thrives best is seldom suited to agriculture, because too wet or too liable to frequent overflow. It is, therefore, a waste-land tree,

and is in little danger of extermination to give room to field crops. Though the supply will never be large, it will probably continue. The wood possesses no properties which will cause it to be sought out for special purposes. It is a plain, reliable wood, often used, but never particularly sought after.

Like the paper birch, it is easily identified by its bark, but unlike the paper birch, its bark has no value. In general appearance it is one of the most ragged and neglected-looking trees in the woods. The loose outer bark hangs in shreds or torn strips, and beneath the rents the delicately colored pink-brown young bark is visible.

USES.

The wood of river birch has no characteristic figure or grain. It does not appear to be used for any purpose on account of attractive or artistic appearance. It is as plain a wood as can be found in the forests of this country, and all its uses are based on service or convenience. In Louisiana the logging operators consider it one of the best obtainable woods for ox yokes, many of which are needed. It is stronger and stiffer than white oak, and much lighter, but the principal property recommending it for yokes in Louisiana is its resistance to decay in a climate and under conditions that are very trying.

In Tennessee the slack coopers have found that river birch makes good barrel headings, and it is sometimes employed in preference to other good woods. In eastern Maryland the manufacturers of peach-baskets draw supplies from this wood, and substitute it for white elm in making the hoops or bands which stiffen the top of the basket and provide a fastening for the veneer which forms the sides. The birch bends in a satisfactory manner, which is an important point, and in that part of Maryland it is considerably cheaper than elm. In some of the southern States it has been manufactured into flooring for use where service rather than appearance is the chief consideration. It is said to bear considerable resemblance to tupelo as flooring where hard service is required, notably in warehouses, barns, and factories. In many localities it is listed as furniture wood, but usually as interior stock, to strengthen or constitute frames which are to be overlaid with veneers of costlier woods. It is not regarded favorably where high polish is wanted, or where fine varnish or oil finish is to be applied, and for that reason its use as an outside wood in high-class furniture or interior house finish has been rare, although it has been made into mantels in Tennessee, and into spindles for stair work elsewhere.

This wood enters pretty generally into the manufacture of woodenware within its range, but statistics usually do not mention it by name. Observation at a number of woodenware factories in the South has shown this species pretty generally in the log yards, though

not in large quantities. It is employed in the manufacture of picnic plates, pie plates, butter dishes, washboards, small handles, kitchen and pantry utensils, and ironing boards; and is said to possess qualities fitting it in a high degree for wooden shoes, which are now made in considerable numbers in this country. It is light, impervious to water, and is not difficult to work.

SUGAR MAPLE.

(*Acer saccharum.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—43.08 pounds per cubic foot (Sargent).

Specific gravity.—0.6912 (Sargent).

Ash.—0.54 per cent weight of dry wood (Sargent).

Fuel value.—92 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—16,000 pounds per square inch, or 125 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—2,019,000 pounds per square inch, or 153 per cent that of white oak (Sargent).

Wood heavy, hard, strong, tough, narrow-ringed, compact, susceptible of a fine polish, color light brown, tinged with red, sapwood lighter.

Height, 75 to 120 feet; diameter, 1½ to 4 feet.

SUPPLY.

Sugar maple is known in different regions by different names, among them being hard maple, which is more general among lumbermen and manufacturers than sugar maple. The wood is little if any harder than several of the other species of maple in this country. Another name is sugar tree, common among producers of maple sugar. It is often known as rock maple, though a number of other maples are known by the same name. In some parts of the South it is called black maple, or simply maple.

The census of 1909 gave the cut of maple in the United States as 1,166,604,000 board feet, but exactly how much of this was sugar maple is not possible to determine, since in compiling the statistics all maples were classed together. It is reasonably certain, however, that it forms three-fourths of the reported output of maple in this country. Nearly one-half is produced by Michigan, and in quantity of cut that State is followed in the order named by Wisconsin, Pennsylvania, New York, and West Virginia. In all, 34 States reported a cut of some species of maple in 1909, but some of them, notably those in the far Southwest, did not produce any sugar maple, and those in the South produced very little.

The commercial range of sugar maple is roughly confined by the international boundary line from New Brunswick to Minnesota, and southward to North Carolina and Kentucky; but cutting is done here and there outside of these boundaries. The total remaining stand

of this wood in the United States has not been carefully estimated. In 1908 and 1909 a reconnaissance of the timber stand in Kentucky credited all species of maples in that State with about 2,000,000,000 feet. Kentucky is not classed among the maple States, and is probably much below some of the others in quantity. Well-posted lumbermen in Michigan are of the opinion that maple in their State will be cut out in 15 years. At the present rate of cutting a 15-year supply would mean a present stand of about 8,000,000,000 feet. That, however, should be accepted only as an approximation, with the probability that it is too high. The earliest estimate of maple was made prior to 1791 for New York and Pennsylvania by Benjamin Rusk. It could have been little more than a guess on his part, and was probably much too high. In a letter to Thomas Jefferson, published in 1791, he said the two States had 300,000,000 maple trees. If the trees averaged 400 feet each, which is a high estimate, the total stand of maple in the two States was 120,000,000,000 feet. It is doubtful if the entire United States has one-third that quantity of maple now, counting all species.

The sugar maple is in no danger of disappearing from the American forest. It is a strong, vigorous, aggressive species, able to hold its own with any trees on soil suited to it, but it is not a "poor-land" tree. In the north, from New England westward through the Lake States, and southwest to the Ohio and Potomac Rivers, few other species are oftener seen in woodlots. It is slow growing, compared with cottonwood, white pine, and some others, yet it is everywhere in favor.

It is seldom hand planted, because it does not need to be. It is one of the surest and most prolific seeders in the forest, the percentage of germination is high, and the ample wings on the seeds insure their being well scattered. The tree endures shade well, and frequently crowds all competing species out and develops pure stands. In some parts of New England and in the Lake States it takes possession of cut-over lands. When once established it is proof against encroachment by other species. In Michigan it is not unusual for maple to take possession of land from which pine or hardwoods have been cut clean, though such land must be fertile and reasonably well drained.

Sugar maple, in short, promises to become one of the permanent forest and woodlot trees of this country, though it grows slowly. The intrinsic value of its wood is high, and its range of uses is among the widest.

EARLY USES.

Maple shared the fate of many other valuable woods in the early years of the country's settlement, when what could not be used was destroyed. In Rusk's letter to Jefferson, already quoted, he esti-

mated that 6,000 maple trees were destroyed in clearing the average New York or Pennsylvania farm.[1] He suggested that one-third of them should be left standing, not for the wood but for the maple sugar they would yield. He presented figures which he thought proved that the maple trees of the eastern part of the United States could meet a large part of the world's demand for sugar.

It was not possible for the early settlers to use the countless thousands of maple trees cut in clearing land. There were, however, some ways in which they could use part of the timber. Household fuel was always in demand. The large open fireplaces sent probably 90 per cent of the heat up the chimney, but wood was plentiful and was piled in the fire with the utmost liberality. Maple backlogs were in special demand. Long after it had ceased to be a virtue to burn as much wood as possible the farmer laid in his supply of maple backlogs for the winter. As early as 1807 maple fuel was shipped from Maine to Boston.

Charcoal burners cut maple when they could get it. Iron furnaces consumed large quantities in Pennsylvania, New York, Vermont, and elsewhere. Blacksmiths wanted maple charcoal for forges, and this created a wide but not large demand. The charcoal was in demand by gunpowder makers, too, and some of the superfluous maple timber was put to that use, although not enough to make a perceptible inroad on the supply. Potash manufacturers preferred this wood. A century ago the potash shipped from New York and Boston was 80 per cent of maple. The value of maple in the potash industry will be further considered under the heading "Ashes," on page 46.

The characteristic rifle stocks of pioneer days were usually of curly maple, because the wood was strong and stiff and could be worked down very small without endangering its usefulness. The wood was carefully selected to display the curly and bird's-eye effects to best advantage.

Violins were not abundant in this country in early times, but they were occasionally made, and the material was largely figured maple. The makers of those instruments constantly kept choice maple in stock, air-drying it during several years.

Runners of sleighs were largely of maple, and sled soles were frequently made of it. Occasionally it was made into ox yokes. The wood has great strength under constant strain, but is apt to break by sudden jar.

Various articles of household necessity were made of maple, such as rolling pins, potato mashers, butter printers, bread boards, chopping blocks, ladles, and bowls. A place for it of more than ordinary

[1] Transactions of American Philosophical Society, vol. 3, p. 64.

importance, given because of its hardness and smoothness, was in the homemade spinning wheels found in most pioneer cabins where flax was spun. These were known as "little wheels" to distinguish them from the "big wheels" employed almost exclusively in spinning wool. The reel, a companion piece to the spinning wheel, generally had maple for the crosspiece on which the thread was wound.

The old-fashioned shoemaker fastened his soles with maple pegs when he could not get pegs of paper birch. Before they were split and pointed by machinery he whittled them by hand. Lasts of maple were the usual thing, though other woods answered very well.

Maple saddletrees were part of the stock in trade of most saddle makers in pioneer times, as at present. The millwright made his cogwheels then, and the teeth of the homemade pinions and trundle-heads were frequently of maple, provided they were not to be exposed to dampness. Maple filled a number of places in early shipbuilding, though it was of less importance than some other timbers. Maple knees, keels, and keelsons are mentioned in shipyard supplies. Maple broom handles were in use nearly a century ago, and their handsome appearance and the good service they gave were subject of special mention.

Maple has been a furniture material ever since furniture has been made in this country. Chair makers seem to have been among the first to discover its good qualities. When mahogany was the fashionable furniture wood curly maple was a choice inlay. It is not unusual to find antique pieces of rare beauty and generations old. The white wood contrasts well with the darker mahogany. Sometimes sugar maple was used, sometimes red maple.

Maple lumber in early times was not much used for building purposes. An occasional exception was found in kitchen floors. The boards were from 6 inches to a foot wide, wore smooth, and became very hard. Service was what was wanted, and maple gave it.

Wooden dishes were comparatively more common in the years succeeding the earliest settlement of the country than they are now, because then many persons were under the necessity of making nearly all of their household articles. John Lawson, whose writings were published in 1714, gives maple a place of honor as material of which "dishes, trenchers, and spinning wheels" were made in the Carolinas.

It was among the earliest of the hardwoods exported, and special mention is made of its use at Keighley, England, in the manufacture of washing machines and mangles.[1]

The Iroquois Indians of New York made paddles, spoons, and ladles of sugar maple. The only recorded attempt of the American Indians in manufacturing and employing cannon to attack forts occurred during the siege of Fort Henry (now Wheeling, W. Va.)

[1] The Trees of Commerce, William Stevenson, edition 1908.

in 1777, when they made their cannon of a maple log and wrapped it with chains. They fired it only once, however, for it burst with disastrous results.[1]

No sharp historical or geographical line separates the primitive and local uses of maple from the employment of the wood for manufacturing purposes, as the term is now generally understood. The change was gradual and went on in many places until what was a century ago a material whose very abundance often made it a nuisance has become one of the most important woods in American factories. It began to enjoy a high place when special commodities, manufactured by machinery, found general sale.

FLOORING.

The making of matched flooring by planing mills may be considered as the beginning of the flooring industry. Between 1870 and 1880 attempts were made to introduce floors of maple and black walnut in alternate strips. When well finished the effect is pleasing. The rich black of the walnut and the clear white of the maple were attractive, but the floors were not satisfactory when subject to severe use. The walnut was softer and wore more rapidly than the maple, and the floors became uneven. Wainscoting of the same kind had been introduced to match the flooring, and though not subject to wear, it lost its popularity when the combined walnut and maple floors went out.

Soon after this the roller-skate craze struck the country, and maple flooring was instantly in demand. It was the best obtainable material for rink floors. Its permanent place in the lumber industry may be dated from that time. Its good service in rinks led to its use for other floors, and also for finish, and then for furniture. At the present time half the maple output is for floors. Care in seasoning and laying it is necessary, for if placed green it shrinks badly, or if dry when laid and later allowed to become damp it swells up in ridges. But when properly managed it is one of the very best of floor woods with lasting qualities of the highest order. Instances have been cited, apparently well authenticated, where maple has given longer service under excessively trying conditions (stair landings in large stores) than marble.

The modern manufactured flooring is much narrower and often much thinner than the old-style flooring turned out by sawmills generations ago. Modern flooring varies in width from an inch to $2\frac{1}{2}$ or 3 inches and in thickness from three-eighths of an inch to thirteen-sixteenths of an inch. It is dressed true, and the tongues fit into the grooves almost perfectly. The three-eighths-inch flooring

[1] Chronicles of Border Warfare, Alexander S. Withers.

weighs about 1,200 pounds per 1,000 surface feet; the five-eighths-inch weighs 1,800 pounds; and the thirteen-sixteenths-inch weighs 2,100 pounds. These weights are for thoroughly seasoned wood. Flooring is often made of other species of maple not quite the same in weight as this.

Sugar maple is one of the woods employed in the manufacture of parquet flooring, but the quantity demanded by that industry is comparatively small. Maple often composes the white wood blocks and strips in that work and is combined in patterns with woods of darker color.

LASTS.

Several woods are listed as last material, but maple greatly exceeds all others. The annual demand in Massachusetts for this commodity is about 13,000,000 feet, and in Michigan a little more, and these two States are among the highest in last production. The reports from these two States mention no wood other than sugar maple, except that softwoods serve for lasts or "trees" for rubber boots and shoes.

Maple is considered the best for lasts because it is hard, finishes smooth, checks but little when carefully seasoned, and does not warp out of shape. The wood is carefully selected, and none but the best is used. Knots or other defects spoil it for lasts. Billets or bolts are split from logs usually sawed long enough for three lasts. Each billet therefore makes three last blocks. The seasoning is carefully done and is a slow process, for before the wood is placed in the kiln it is air dried for from one to two years. The last maker will reject a block containing season checks or cracks, which will not be cut out when the last is turned in the lathe.

There are as many sizes of lasts as there are sizes of shoes, and there is as great variation in style as in size. Every change in fashion of footwear, moreover, demands a change in lasts. This year's style of shoes, if different from what went before, can not be made upon old lasts. For that reason old stock must frequently be laid aside or thrown away and a new and different style substituted. This gives the last makers a constantly changing field of trade.

Lasts are usually made by machinery, but every one is turned exactly like a pattern, and the pattern must be slowly and carefully whittled out by hand. The making of the pattern is the most exacting work in the trade. When a new style of shoe is demanded the pattern maker is set to work to produce the model. He uses maple for the most part, and when he has worked it down to satisfactory shape and size the corners and angles are covered with steel to resist the wear of the machinery. It is fixed in the lathe and revolves hundreds of times for every last that is made like it, and a machine

should make a hundred or more a day. A considerable amount of sugar maple is shipped to England, where it is manufactured into lasts. Lasts made in this country are shipped to all parts of the world where people make leather shoes, but the best market is in the United States. The final purchasers are not only the large manufacturers but every shoemaker and cobbler throughout the land.

The waste of wood in such a factory is large. From one-half to two-thirds of the rough split block is cut away as dust and shavings.

BIRD'S-EYE MAPLE.

A large use of maple wood for furniture, musical instruments, and interior house finish is due to a pleasing growth called "bird's-eye," which adds much to the beauty of the wood when highly polished and carefully matched. The most probable explanation of this figure is that it is due to buds, which for some reason can not force their way through the bark, but remain just beneath it year after year during long periods. The young wood is disturbed each succeeding season by the presence of the bud and grows around it in fantastic forms. When such a tree is converted into lumber, the saw cuts through the abnormal growths, exposing the crumpled edges of the tilted annual rings.

Curly and wavy maple are accidental forms which frequently occur and are highly prized by furniture makers and other manufacturers of high-class commodities.

FURNITURE.

Sugar maple stands near the top of the list of furniture woods in this country. Statistics have never been collected to show the comparative rank of different species in quantity used, but white oak is probably first. Sugar maple is third in Massachusetts, third in Maryland, first in Wisconsin, and second in Michigan. Some woods are given place in furniture making only as inside, concealed material, others only as the outside, visible portion, but sugar maple serves in all parts. It is strong, rigid, and durable as frames and as slides for drawers and the sections of extension tables. It may be used in the form of very thin lumber, or as built-up sections of veneer, for the bottoms of drawers and partitions between compartments in desks and filing cabinets. Its white color is one of the qualities which fit it for that place. A coarser class of service is found for it in the manufacture of cot frames and the frames of couches, as well as for almost all kinds of furniture. Its hardness makes it suitable for casters for heavy articles of furniture. It is difficult to split when well seasoned, a quality in which many hardwoods are found deficient. Three-ply maple veneer is much employed for chair seats and backs. Maple stood third highest in the United States of all woods

used in the manufacture of veneer in 1909, but only a portion of the veneer found place in furniture making. In quantity maple (all species combined) was surpassed by red gum and the southern yellow pines.

Sugar maple is a choice wood for kitchen cabinets, tables, and shelves. It is clean and white, so hard and dense that it does not readily absorb impurities, and its surface is easily washed.

A rather large quantity of it is made into mission furniture, some of which is left in its natural color. The wood may be stained a green gray by applications of copperas water. The makers of willow and rattan furniture employ sugar-maple rods to give form and strength to their commodities.

The bulk of the first-class maple demanded by furniture manufacturers is made into bedroom suites, wardrobes, house desks, library tables, wall cases, bookshelves, chiffoniers, rockers, children's cribs, and similar articles. It is here that the bird's-eye and curly maple are most frequently seen and where the artistic workman can most effectively display his skill. The best bird's-eye stock is generally reduced to veneer and spread in thin sheets over scores of cheaper woods.

INTERIOR FINISH.

The use of high-grade figured maple as interior finish does not differ much from its employment in furniture making. The best wood is reduced to veneer and laid on cheaper backing. Wide panels in ceiling or wall are possible, for the veneer may be had in large sheets, cut by the rotary process. The manufacturers of material of that grade discourage the employment of fillers preparatory to finishing the work, but recommend natural colors.

The general use of maple flooring calls, in many designs, for interior finish to match. Stairs are made of the wood. It wears well where use is hard, and it carves well where ornamentation is desired.

Maple doors are in wide demand. They are heavy, but are slow to warp or sag, and give little trouble on account of getting out of shape.

Fixtures for stores and offices, such as counter tops, shelving, cabinets, show cases, display racks, and seats and benches, are occasionally of maple, though generally darker woods are better liked.

VEHICLES.

Sugar maple is very strong, but its tendency to break by sudden jolt or jar places it at a disadvantage in some parts of certain kinds of vehicles, yet it has a wide range of uses in which it gives satisfactory service. It is maintained by some that tapping trees in the process of sugar making weakens the wood by the introduction of incipient decay; but as far as the commercial use of the wood is

concerned the matter is not important, for a very small per cent of the maple lumber on the market is from tapped trees. Wagon axles of sugar maple are considered by some as good as any. The heaviest two-wheel log trucks used in Michigan have axles of this wood 8 inches square, with wheels 10 feet high. Such an axle sometimes carries 20,000 pounds over rough log roads. Maple is employed for wagon beds, though its weight is against it, as frames for buggies, dashboards for carriages and light business wagons, and its use for buggy shafts has been reported in Kentucky. It is widely employed in the manufacture of small vehicles, as baby buggies, go-carts, and children's wagons. It is good sled material and is one of the common woods in cutter and light-sleigh manufacture, entering into practically all parts of the vehicles, but is particularly liked for the soles of heavy sleds. Its hardness and smoothness insure easy running and long service. Sugar maple is recommended for handles and other parts of gocarts and for baby carriages which are to be finished in white enamel. The wheelbarrow manufacturer, in certain localities, employs scarcely any other wood, while in other places the handles are of sugar maple and the body of white elm or some other tough wood.

Car builders make use of maple for many purposes and in cars of many kinds. Its white color gives it a value as finish for the interiors of electric cars, and occasionally for steam coaches and Pullmans. Service of a different kind is found for it in log cars, where it goes into frames and bunkers. Platforms of push cars and trucks employed about factories and railroad stations are frequently of sugar maple, as are the frames of railroad velocipedes.

An important demand comes from manufacturers of bicycle rims, and this rather small commodity requires several million feet annually of select maple.

The rapid rise to importance of automobile manufacture has created a new demand for sugar maple, largely for benches, bottoms, subfloors, and frames.

HANDLES.

As a handle wood sugar maple is not in the same class with hickory. The latter is demanded more for its toughness and resiliency than for its strength, though the latter quality is duly considered. Maple is not tough or very resilient, but it is nearly as strong as hickory. Its important position as a handle wood is due chiefly to its hardness, smoothness, strength, color, and cheapness. It is not well suited for ax handles or slender hammer handles, because sudden jars are likely to snap it; but for stiff handles, not subject to much bending, it is one of the best available woods. It is not known how much of it is made into handles, but the total is probably not much below the

quantity of hickory. The largest part doubtless goes into broom and mop handles. The State of Michigan alone puts more than 20,000,000 feet of the wood to that use annually, and in Wisconsin sugar maple is the principal material in the broom-handle industry. Next to white birch it is the leading handle wood in Massachusetts. Farther south it is not so plentiful and does not attain to the important place it holds in the north.

Sugar maple contributes liberally to a very large class of small handles for tools, such as chisels, augers, gimlets, gauges, hammers, mallets, monkey wrenches, and especially the tools used by wood engravers, shoemakers, and tanners, and by tinners and other sheet-metal workers. Maple is one of the many woods used for pail and package handles, which are made in large numbers. In the manufacture of whip handles in Massachusetts sugar maple holds first place. Brush handles of all kinds also draw heavily upon this wood.

The makers of cant-hook handles select clear maple that will split nicely, for there must be no cross grain. The cant hook and the similar tool called the peavey are used for rolling logs and are subject to great strain, but not often to sudden jolts, and strength is the main thing. If these handles are made from sawed squares, cross grain may result, rendering the tool unreliable. The snapping of a cant-hook handle at a crucial moment may not only defeat the logger's efforts, but endanger the lives of the men by precipitating a skidway of logs upon them. Sugar maple is employed for several tools, such as handspikes, levers used in mills and in turning capstans on shipboard, and for pickeroons or poles with pikes used by log drivers on rivers.

Snaths, or the bent-wood handles of scythes, are split from logs to make sure there is no cross grain. Sugar maple, however, is not as often employed as white ash, hickory, and red mulberry. Other bent-wood handles occasionally manufactured from sugar maple are for parasols and umbrellas. Here, too, maple is not as important as some other woods, and in quantity it is perhaps surpassed for umbrella handles by the diminutive nannyberry bush of New Jersey (*Viburnum prunifolium*).

MUSICAL INSTRUMENTS.

When sugar maple is made the outside, visible wood of pianos, bird's-eye or curly growth is generally selected. Maple is rarely finished to imitate any other wood. The bird's-eye maple is frequently seen in violin sides and in other small instruments, but the curly or wavy growth is usually preferred where the surface exposed is small, because it can be displayed to better advantage than the bird's-eye. Though occasionally accorded a prominent place as an outside wood in the making of musical instruments, maple is oftener hidden

within. In piano construction it goes into the action parts, the bridges and pin planks. Player pianos nearly always use some maple. It is often found in banjos, guitars, mandolins, and in music boxes and talking machines. Its use in music cabinets, racks, and in piano stools and benches perhaps should be listed as furniture. The hoops of drums, and the shells also, are frequently maple. Young growth, called second growth by some manufacturers, is preferred for drum hoops, because it bends more readily than old wood. Some of the best selected bird's-eye and curly maple is seen in expensive harps. Illinois is one of the largest centers of the manufacture of organs and pianos, and in that State, according to reports compiled in 1909, more sugar maple is used than of any other of the 29 woods demanded by those industries. Chestnut stands second in that State. In the manufacture of musical instruments of all kinds, sugar maple stands second for quantity in Massachusetts, third in Michigan, and fourth in Wisconsin and Maryland.

AGRICULTURAL IMPLEMENTS.

The list of apparatus, appliances, and machinery included in the general term agricultural implements is so long and varied that their enumeration is scarcely practicable; yet through the entire list sugar maple holds an important place. In Illinois, which probably produces much more farm machinery than any other part of the country of an equal area, 20 woods are given in reports on this industry. Of the five most important, sugar maple stands first.

	Feet.	Cost.
Sugar maple	24,564,000	$931,970
Longleaf pine	24,159,000	688,924
Shortleaf pine	15,600,000	405,870
White oak	10,366,000	481,956
Cottonwood	5,469,000	193,504

The 15 other woods entering into the manufacture of those commodities in Illinois total 23,491,000 feet.

In few cases in the making of agricultural apparatus is maple or any other wood employed solely for appearance. Strength and hardness are the prime requisites, and sugar maple enters all parts of machines where strain or wear must be resisted. Statistics of the woods employed by makers of farm machinery and apparatus in the State of Michigan show that sugar maple enters largely into bean pickers, baggers, corn shellers, corn huskers, corn planters, cultivators, ensilage cutters, feed cutters, grain separators, fanning mills, hay balers manure spreaders, potato planters, self-feeders, shredders, thrashing machines, wind stackers, horsepowers, and riddles, as well as into many utensils classed as tools rather than machines, such as hand rakes, grain shovels, pitchforks, measures, feed troughs, and snow shovels.

In the manufacture of farm machinery, however, maple does not go as far outside its geographical range as do some other woods, particularly longleaf and shortleaf pine of the South. The use of maple for that purpose declines rapidly as the distance from the source of supply increases. In North Carolina, Kentucky, Arkansas, Louisiana, and Missouri sugar maple is not very important in the manufacture of agricultural machinery. Other woods can be procured at less cost. However, there are no centers in those States where farm machinery is made on a large scale as there are in Wisconsin, Michigan, and Illinois, near the maple supply.

WOODENWARE.

Sugar maple is widely utilized in the manufacture of woodenware. Some factories making pie, butter, and picnic plates use maple exclusively; others accept nearly any hardwood that has no pronounced taste or odor. A brief summary, but by no means a complete list, of woodenware into which maple enters would include bread boards, meat boards and the tops of tables where meat is cut, rolling pins, meat mauls for pounding steak for broiling or frying, wooden spoons, butter ladles, molds, printers, bowls, churns, especially the dashers, lemon squeezers, kraut cutters, and potato mashers. In articles of this class it is highly important, for sanitary reasons, that the wood be sufficiently hard to resist bruising and splintering, and it should not check and present open crevices in which organisms or impurities can find lodgment. Sugar maple meets these requirements better than most other woods. Its hardness, nevertheless, is in one way disadvantageous because of difficulty in working it.

A class of woodenware made in cooperage factories is used for the shipment of food products, and sugar maple is one of the woods employed. In the making of sardine kegs the hoops and staves are of maple and the heading of white ash. Anchovy kegs frequently have willow hoops, but the heading and staves are maple. Lard tubs, butter tubs, and cheese boxes are often of sugar maple, and it is one of the best woods for faucets. Many kinds of pails are of the same material, especially sap buckets used by sugar makers in the North. Flour barrels and sugar hogsheads belong properly to slack cooperage, and maple is often employed in their manufacture. In the United States Census reports for 1909 this wood was credited with 118,000,000 staves, 13,000,000 sets of heading, and 700,000 hoops.

The use of sugar maple in certain kinds of woodenware is not due to absence of taste or of staining material in the wood, but to desirable features, such as hardness, smoothness, agreeable color, and cheapness. Garment hangers are in that class, also display racks and dummies, candle pins, and a pretty complete line of apparatus for the

laundry, including washing machines, wringers, mangles, towel racks, ironing boards, sleeve boards, wash benches, washboards, clothes racks, and clothespins. In the same class belong cigar boards, where the tobacco leaves are cut and rolled, and lapboards on which the cobbler, saddler, and harnessmaker trim leather and fashion it. The clamps for holding articles while working on them are frequently of sugar maple.

MISCELLANEOUS.

The miscellaneous uses of sugar maple are so many that little more in the way of enumeration can be attempted than to indicate the industries where they are found, and even this outline must be incomplete.

Wherever the maple grows in commercial quantities it is made into shipping boxes and crates, but it is seldom specially sought after for this purpose. It is heavy and adds to the freight item, but it is strong and stands hard usage. The shippers of tin plate place it among the best woods in their business, and in that instance special effort is made to get it. Furniture factories use large quantities of low-grade maple for crating. They like it, not only because it is strong and dependable, but also because it holds nails well. Large numbers of very light boxes of veneer are made for shippers of berries, small fruits, and for some kinds of garden truck, such as string beans, celery, young onions, and spinach. Maple boxes are not often used for shipping bulky merchandise. Veneer boxes, but with ends and center partition of thicker wood, are exported as shooks to Sicily for shipping lemons.

Many built-up butcher blocks are of sugar maple. The old-style block, all in one piece, was objectionable on account of season checks which provided lodging places for impurities. Formerly most of the blocks were of sycamore, all in one piece, but maple now seems to be more largely used. However, in the two States of Illinois and Michigan the annual demand for butcher blocks is 1,600,000 feet of sycamore, 1,300,000 feet of maple, and 1,300,000 feet of beech. Maple skewers are nearly everywhere listed in butcher supplies, and veneer sausage trays of the same wood are used by retailers.

Printers and bookbinders are large purchasers of sugar-maple products. Type cases, and often the stands and cabinets where they are kept, are of this wood, as are mallets, furniture (small quadrangular pieces), planes, and wooden type. Preparation of the wood for type is very careful, often including boiling in water, air drying many months, then kiln-drying, and finally oiling. Base blocks for mounting stereotype and electrotype plates and halftone and zinc engravings are frequently of this wood. It is also a liberal contributor to artists' material. It is made into easels, maulsticks,

rules, palettes, picture frames, and panels on which pictures are painted.

Its use in the manufacture of athletic goods and apparatus and in the boards and other paraphernalia for games is general. It is frequently seen in baseball bats, croquet balls and mallets, billiard cues and rings, and in dumb-bells, horizontal bars, Indian clubs, and carom cues and rings. Bowling alleys find no wood better suited, and it is made into tenpins and racks and into frames for boxing machines.

In the manufacture of shuttles, spools, and bobbins sugar maple holds an important rank. It stands first in North Carolina (though some silver maple may be included) and second in Massachusetts, where it is exceeded by paper birch. It is often seen in large spools made in three pieces, it being the central shaft on which the ends are fastened. The wood is made into picker sticks for cotton mills in North Carolina, and forms parts of looms and weaving and spinning machines.

Carpet sweepers are often made of maple, and the easels or racks where the sweepers are kept when not in use are of the same material. It is a common material also in the manufacture of school apparatus, such as stands for globes, frames on which to display charts, blocks illustrating mathematical forms and figures, and material for manual training classes.

Round measures, sometimes called "nest boxes," are frequently of this wood, particularly the bent wood forming the sides. This is of thick veneer, usually one ply, but occasionally three. The utensils are used in grocery, grain, and seed stores, and by millers and farmers. In capacity they range from a pint to a bushel. Sieve rims belong in the same class.

Sugar maple competes with black gum for first place in the manufacture of rollers of many kinds—those employed in moving houses and other very heavy bodies; in off-bearing tables of sawmills; in shoving timbers ashore from ships and boats; and in mines as runways for cables. The wood is exported to England for mine rollers. Land and lawn rollers of several sizes are made of sugar maple.

The pipes employed to carry away the impure water from coal mines, particularly the Pennsylvania anthracite mines, are required to withstand strong chemicals. Many operators prefer wood to metal, and maple is among the best woods for the purpose. Similar pipes serve in tanneries and packing houses.

In Massachusetts maple is more largely employed in brush-back making than any other wood except paper birch. It is in demand for blue-print frames and the printing frames used by photographers, for die blocks and die-block cases, and for gas-engine skids and the frames for portable sawmills. Pulley makers find the strength,

hardness, and smoothness of maple serviceable in their business. Rings of many sorts and sizes are manufactured from this wood—curtain-pole rings, gymnasium rings, martingale rings, and many used in industries, games, and arts. Canes and crutches are in the list of maple commodities, as are tripods for photographers and surveyors; screws, gauges, and benches for carpenters and other mechanics; and tool chests for workmen.

Fuel makes very heavy demands upon sugar maple. It is cut in the woods, but the largest supply of fuel probably comes from slabs at sawmills and tops and limbs left in the woods by log cutters. The mills in Michigan and Wisconsin which saw maple logs find large sale for slabwood in Chicago, Milwaukee, Detroit, Cleveland, Toledo, and other cities and towns on the Great Lakes.

DISTILLATION.

Maple is one of the three principal hardwoods used for distillation, the two others being beech and birch, as previously described.

ASHES.

Ashes are so often a waste product that their value is seldom thought of, yet they have been and still are of industrial importance. Sugar maple stands first as a producer of the commodity. Almost immediately after the settlement of this country the colonies shipped ashes to England. In 1621 the Virginians were selling it there at 6 and 8 shillings per 100 pounds, but the different species which produced the ashes are not recorded. Later 80 per cent of the ashes exported from Boston and New York was made from sugar maple. In the maple regions just over the line in Canada the burning of ashes was made a business, and doubtless the same business was found in near-by parts of the United States. Annual exports of potash and pearlash from Canada, at a comparatively recent period, represented 20,000 barrels of ashes. Most of the material is used to make soap for the British Navy.[1]

The use of ashes in this country in former times for making soap was very general. In farmhouses and villages each family made its own, just as it made its own clothing and shoes. Wood ashes—not necessarily maple, though that was considered best—an ash hopper where the leaching was done, a lye trough, kettle, grease, and a sassafras soap stick for stirring constituted the usual rural family soap-making establishment.

Ashes, maple and hickory preferred, were once in very general use for curing meat, particularly bacon. At the present time some of the largest meat packers in this country smoke bacon with sugar-maple wood. Thousands of cords a year are so used.

[1] "The Potash Salts," L. A. Groth, London.

The largest demand for wood ashes in this country has always been for fertilizers. It is claimed that the Massachusetts Indians taught the Plymouth colonists the value of ashes in growing crops.[1]

SUGAR.

There is no account of the beginning of sugar making from the sap of maple. The Indians from Carolina to Canada knew the art before white men came.[2]

The first settlers made sugar as soon as they came in contact with the sugar maple. They imitated the Indians at first, though their tools and apparatus were better.

There is wide difference in the quantity of sugar which single trees yield in a season, the range being from 2 to 40 pounds, the average, however, not being much above the lower figure.[3]

It is usually considered that from 16 to 20 quarts of sap make a pound of sugar. This article is now generally regarded as a luxury, if it can be had pure, but it was formerly not much used by persons who could afford to buy West Indies cane sugar. In 1791 it was published, with evident patriotic pride, that Thomas Jefferson used maple sugar exclusively, and that to assure a future supply at his farm near Charlottesville, Va., he had planted a grove of maple trees.[4]

Exact figures on the sugar and sirup output are difficult to obtain, because many farmers do not make returns to the collectors of statistics, and, further, because much of the product is adulterated before it reaches market. In many cases maple sugar is used to flavor sirup or sugar made from cane or beets. Hickory bark also has been used as flavoring material. Adulterations of maple sugar and sirup have been many and widespread.

BLACK MAPLE.

(*Acer saccharum nigra.*)

The black maple is a form of sugar maple which is found from New England to South Dakota, eastern Kansas, Arkansas, and west of the Allegheny Mountains to northern Alabama and Mississippi. It is the same as sugar maple in weight, but contains more ash. It is weaker and less stiff than the other wood, and in these two properties its greatest differences from the former species are seen. In some regions it is scarce; in others it exceeds in quantity the associated species of maple. It is the only sugar maple in South Dakota. It is

[1] "Fertilizers," Edward B. Voorhees.

[2] The Indians of Dakota and of Ohio were reported as sugar makers. A place in Ohio, 20 miles from the Muskingum Ford, was known as "sugar cabins" long before white people had settled the region. See "The Journals of George Croghan," published in vol. 1 of "Early Western Travels," by Reuben C. Thwaite.

[3] "Sugar Maple and the Sugar Bush," A. J. Cook.

[4] "Transactions of the American Philosophical Society," vol. 3, p. 78.

generally used for the same purposes as sugar maple, but figures showing quantities can not be compiled, because this wood is seldom reported under its own name. Occasionally it is called black sugar maple, and more frequently hard maple.

RED MAPLE.

(*Acer rubrum.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—38.5 pounds per cubic foot (Sargent).

Specific gravity.—0.6178 (Sargent).

Ash.—0.37 per cent weight of dry wood (Sargent).

Fuel value.—83 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—11,400 pounds per square inch, or 91 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—1,297,000 pounds per square inch, or 98 per cent that of white oak (Sargent).

Heavy, hard, strong, compact, easily worked, medullary rays obscure, color brown, often tinged with red, the sapwood lighter.

Height, 75 to 100 feet; diameter, 1½ to 3 feet, occasionally larger.

SUPPLY.

Red maple grows from Canada to Florida and westward to Wisconsin, Iowa, and Texas. It reaches its best development in the lower Ohio Valley and thence southward to the valley of the Yazoo. In some portions of its range it is abundant, but in others scarce, and estimates of the commercial supply can not be made with any accuracy. Statistics of lumber cut throw little light on the subject, for the various species of maple are all grouped as one. In some instances, as in the case of broadleaf maple of the Pacific coast, the region is a guide to the species, but that does not hold for red maple, because several of the species are lumbered in the same region with it. In most instances, lumber cut from red maple passes for sugar maple. There is some difference between the woods of the two species, but not enough to be distinguished by the ordinary user. Red maple's name does not come from the color of the wood, but from the flowers, which in some situations are scarlet and in others red. The color is so striking that the trees may be identified by it almost as far as they can be seen.

MANUFACTURING.

Because the wood of this tree, when it reaches maturity, is so frequently classed as sugar maple, it is not possible to credit the red maple with all the uses which doubtless belong to it. It is known that the early makers of shoe pegs, who whittled them by hand, preferred this maple to all others. That was a very small use, however. Saddletree makers in early times found in this wood qualities which caused it to be given preference in many localities. Ox yokes de-

manded a small supply, and shovels somewhat more. Rifle stocks of red maple were common, and the claim was made—probably due to a misunderstanding—that the wood occasionally developed a wavy grain not found in any other maples.

In most furniture factories where maple is used some of it is red maple, and special mention is often made of the wood by chair factories. When woodenware was handmade, bowls and trays of red maple were preferred. The modern woodenware factory works the wood into pie and picnic plates, platters, and butter dishes. Box-makers and the manufacturers of crates and baskets for shipping berries and vegetables take the red maple on the same footing as other maples.

In North Carolina it is made into finish for passenger and electric cars. In other regions boatmakers find many places for it, and a considerable quantity goes into the manufacture of vehicles.

The bark of this maple is valued by inkmakers. It is boiled in soft water, and the tannin is combined with sulphate of iron. It is probable that the pioneers resorted to this process more frequently than present-day manufacturers. Domestic dyes also were made of it.

Chemical plants where hardwoods are converted into charcoal, acetates, and other commodities find this maple one of the best woods.

DRUMMOND MAPLE.

(*Acer rubrum drummondii.*)

The Drummond maple is a southern form of the red maple, but is lighter and lower in ash. It is not a commercially important tree, but it serves the people locally. On the lower Red River, Louisiana, a peculiarly fine class of curly and bird's-eye wood of this species has been made into gunstocks and violins. The tree's range includes parts of Tennessee, Georgia, Alabama, Florida, Louisiana, Arkansas, and Texas. Though botanists readily distinguish it from other maples, lumbermen generally do not.

SILVER MAPLE.

(*Acer saccharinum.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—32.84 pounds per cubic foot (Sargent).

Specific gravity.—0.5269 (Sargent).

Ash.—0.33 per cent weight of dry wood (Sargent).

Fuel value.—92 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—14,000 pounds per square inch, or 114 per cent that of white oak (Sargent).[1]

[1] The breaking strength and factor of stiffness were calculated from a single sample cut near Topsfield, Mass. It grew in a low meadow, and broke with long, fine splinters.

Factor of stiffness (modulus of elasticity).—1,482,000 pounds per square inch, or 112 per cent that of white oak (Sargent).

Light, hard, strong, brittle, compact, easy to work; color, light brown; medullary rays numerous, thin.

Height, 60 to 100 feet; diameter, 1½ to 3 feet; individuals occasionally much higher.

SUPPLY.

This tree is known by several names, among them swamp maple, silver maple, water maple, silver-leaved maple, river maple, white maple, and soft maple. The last name is that by which the wood is known among lumbermen, and silver maple is most frequently applied by those who plant the tree, such as nurserymen, park keepers, and the tree departments in cities. The whiteness of the leaves, particularly the under sides, suggests the name silver. It does not refer to the color of the wood, for that of other maples is as white. In fact, the wood of this maple sometimes changes color after it has been exposed to the air, and may become tinged with blue. An early reference to an American maple, believed to have been this tree, noted the blue color of the wood as its chief value in England more than a hundred years ago. "The bog maple," says Stevenson in "Trees of Commerce," "is of a beautiful pale blue color, grows in American swamps, and is sent to England in the form of veneers, and is the most handsome wood that can possibly be conceived. It is made into stationery cases and cabinet work."

The silver maple's commercial range is wide, and conforms pretty well to its botanical range, for wherever the tree grows it is used. Its importance is much below that of sugar maple, and the total quantity is certainly less, though its range is as wide. It grows in all of the States east of the Mississippi River and in several west of it. It grows rapidly, but is subject to injury and is a prey to disease. This is the maple most frequently planted in towns and cities for shade, particularly south of the northern tier of States. The commercial supply of silver maple does not come from planted trees, and probably never will, but the forest growth will be drawn upon for a long time. South of the commercial range of sugar maple, the local supply comes principally from silver maple, and the wood has a wide range of uses.

EARLY USES.

Silver maple was never thought much of as a farm timber, except that it was good fuel. Hatters preferred charcoal of this species for heating their boilers. Furniture makers cut it in strips for inlays in the manufacture of mahogany, cherry, and walnut articles. The white wood contrasted well with the darker material, but the maple did not hold its color well. Age darkened it, and the older the inlaid furniture became the less pleasing it was. Sugar makers tapped

silver maples when convenient, but the yield from them was only half that from the sugar maples. To offset this, in a measure, the sugar from the former tree was white and of milder flavor than that from the sugar maple. Large bowls for household use were occasionally made of silver maple, but it was not a choice material for that purpose and was not often taken when yellow poplar, cucumber, or basswood was available.

MANUFACTURING.

Statistical reports of manufacturers do not usually separate this wood from other maples. The industries which use the wood, however, are well known, as are the commodities into which it enters. Furniture is important, and probably makes heavier demands than any other industry. Sometimes articles are wholly of silver maple, but often it forms only a part. In veneer work it is good core material over which woods more costly or more attractive are laid. In other cases it is the frame, the drawers, or the compartments, while other woods are given the outside positions. This is true of large tables in which oak, birch, or mahogany is visible, with the interior of silver maple. Belonging in the same class are cabinets, wardrobes, large chairs, bookcases, filing cabinets, hall clocks, and bedroom suites. Silver maple is not thus employed because it is better than other available woods, but because it will answer and is convenient and cheap. It is much lighter and weaker than sugar maple. Some prefer it because it is light. When it is made into kitchen cabinets, refrigerators, ice boxes, and pantry shelves and tables it is the outside wood. Its light color and clean appearance are considered in selecting it for this use. Kitchen and camp chairs are occasionally made of it, and it is found in the frames of cots and couches, where its moderate weight is appreciated. The long, pliant branches, an inch or less in diameter, bend easily and are much employed in making rustic porch seats and other outdoor furniture. The manufacturers of lawn swings list the wood among their supplies.

Silver maple is quite satisfactory for interior finish for houses and electric cars. Office and store fixtures, such as counters, shelving, partitions, show cases, and cabinets, are often made wholly or in part of silver maple; and in quality it is only a little below sugar maple for flooring, and is sometimes seen in parquetry, but its tendency to change color with age must be considered when it is combined with other wood to form contrasts. Doors and door frames and stair work draw supplies from it, and it makes excellent molding. In Louisiana the wood is liked for boat floors and in Michigan for boat trim and stairways. It is a substantial wood and in general use in the manufacture of agricultural implements. It does not seem to be selected for this purpose because of special fit-

ness, but because it is convenient and unobjectionable. It is manufactured into tool boxes on mowing machines, reapers, and seed sowers, parts of corn planters, garden cultivators, fanning mills, grass seeders, potato planters, and root cutters. It is most frequently used for hoppers. The largest demand for silver maple in implement work appears to come from Illinois, and the supply is derived from the South rather than from the North. Silver maple reaches its best development and largest size in the lower Ohio Valley.

It is not largely employed for vehicles, but is preferred to many other woods for the handles of baby carriages and gocarts to be finished in white enamel. Children's cribs, for the same reason, are made of the wood. Hand sleds and parts of automobile frames take some of it, and it is used by makers of railroad velocipedes.

Many articles belonging to woodenware show the use of silver maple—veneer plates, butter bowls, bread boards, ironing boards, clothes dryers, mangles, sleeve boards, broom handles, carpet sweepers, and coat hangers. Boxmakers in nearly all parts of eastern United States use silver maple, and often in large quantities. Perhaps more is made into crates than boxes. Egg cases are specially mentioned, and near akin to them brooders and incubators. Signboards, reels on which to wind barbed wire, umbrella racks, picture frames, hay racks, and ballot boxes are in the miscellaneous list of articles in the manufacture of which silver maple finds a place. It is a rather important material in manual-training supplies, school apparatus, tool handles, and professional and scientific instruments.

BROADLEAF MAPLE.

(*Acer macrophyllum.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—30.59 pounds per cubic foot (Sargent).

Specific gravity.—0.49 (Sargent).

Ash.—0.54 per cent of weight of dry wood (Sargent).

Fuel value.—66 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—9,590 pounds per square inch, or 77 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—1,065,000 pounds per square inch, or 81 per cent that of white oak (Sargent).

Light, soft, not strong, compact, easily worked, susceptible of a good polish, medullary rays numerous, thin, color light brown, tinged with red, sapwood often nearly white.

Height, 75 to 100 feet; diameter, 2 to 4 feet.

SUPPLY.

This western tree is known by several other names besides broadleaf maple. It is frequently called Oregon maple, because it reaches

its best development in the southwestern part of that State. Other names for it are white maple and bigleaf maple. Its leaves are sometimes a foot wide, though usually not that large. Its range extends from latitude 55° on the coast of Alaska south to San Diego County, Cal., a distance of nearly 2,000 miles, but east and west it occupies a comparatively narrow strip. In the north it seldom extends more than 2,000 feet above sea level, but in southern California it is found at an altitude of 6,000 feet. In many parts of its range the tree is not of size and shape fit for lumber, but in Oregon a considerable quantity is cut and 2,500,000 feet are manufactured annually into finished products. The shape of the tree is not ideal from the lumberman's viewpoint, the trunk being short. It does not often grow in pure stands, but the trees are dispersed along the banks of streams and on fertile bottom lands. No estimate of the total stand of the species can be made from available data. In 1909 only 12 sawmills in Oregon and 9 in Washington reported this wood in their output, though doubtless many others produced small quantities of the lumber, but did not consider it necessary to include it in their reports. It is not mentioned in statistics of California sawmill output, though it grows in both the Sierra Nevada and Coast Range Mountains over a distance of 600 or more miles.

EARLY USES.

It has been claimed that the broadleaf maple is the most valuable hardwood of the Pacific coast. Some even give it qualities equal to sugar maple of the East. This is claiming more than is shown by a comparison of its physical properties with those of the eastern species, to which it is inferior.

The broadleaf maple was made into gunstocks more than 60 years ago by settlers in what is now Oregon. It produces curly and bird's-eye wood, as do the eastern maples, and that led to a number of uses, though for a long time the total demand was small. The Indians were making bowls of it when the white emigrants reached the northwestern coast. Sugar was made from the sap and supplied the settlers in the new country at a time when other sugar was hard to get. Some of this maple was cut for fuel, but it is rather low grade and so much inferior to some of the oaks associated with it that woodcutters usually passed it by. It served for fences when farms were cleared, but it was no better than several other species which were more plentiful, and, of course, was not hauled far. In a few instances the pioneer water mills in Oregon made broad planks of it, and the settlers floored their houses with maple. Some of the finest stands of broadleaf maple were sacrified when the pioneers cleared their farms, for it grew on the best bottom lands. A very small quantity was made into farm implements, each farmer usually cutting to meet his own needs and working up the wood in his spare hours.

MANUFACTURING.

With the settlement of the country and the multiplication of industries, the native maple was more appreciated. At the present time the largest demand for the wood comes from furniture factories and planing mills which make flooring. Veneer cutters manufacture a panel, glued together three or five ply, which is employed by furniture makers or for the interior finish of houses, offices, stores, and halls. Veneers of cheaper kinds are worked into fruit and vegetable baskets, boxes, and crates. The abundance and cheapness of softwoods prevent much use of maple for merchandise shipping boxes, yet there is some demand, particularly for crating machinery and vehicles. Boat builders on the Pacific coast make finish of the native maple for cabins, railing, frames, doors, and stairways. It serves as counter tops, table tops in butcher shops, show cases in dry-goods stores, and desks in bank and office buildings.

It is a favorite wood for school desks and other furniture, apparatus, and appliances of the schoolroom. Rollers for sawmills, particularly for offbearing lumber, are often of this wood; also large rollers employed in moving houses.

It is selected for molding, particularly the kind used in making picture and mirror frames, carved work, such as pedestals and capitals, newel posts, and various ornaments, grills, spindles, and dowels.

It is considered one of the best handle woods of the Pacific coast, and ax handles are among its uses of that kind, though inferior to hickory and several other eastern woods. Trunk makers use maple slats to reenforce their products, and the wood is good pulley material in machine shops. The pulley maker procures some of his material from the left-overs of furniture factories.

On the Pacific coast maple is considered, next to alder, the best material for broom handles, but it does not appear that the total amount demanded by that industry is large. Its chief commendation is its light color and the good polish it takes, though its comparatively light weight is also in its favor. It is serviceable for pack saddles and tent toggles, and in the mountain regions for snowshoe frames, but the total requirement is small. The western maple is sometimes stained in imitation of white oak and mahogany.

It is not likely that the available supply of broadleaf maple wood will increase, since the natural growth is disappearing, and planting is seldom undertaken.

BOX ELDER.

(*Acer negundo.*)

PHYSICAL PROPERTIES.

Weight of dry wood.—26.97 pounds per cubic foot (Sargent).
Specific gravity.—0.4328 (Sargent).
Ash.—1.07 per cent weight of dry wood (Sargent).

Fuel value.—58 per cent that of white oak (Sargent).

Breaking strength (modulus of rupture).—7,400 pounds per cubic foot, or 60 per cent that of white oak (Sargent).

Factor of stiffness (modulus of elasticity).—805,000 pounds per cubic foot, or 61 per cent that of white oak (Sargent).

Wood light, soft, weak, compact, medullary rays numerous, thin, color creamy white, the thin sapwood hardly distinguishable.

Height, 45 to 75 feet; diameter, 18 to 36 inches, occasionally larger, but in some regions much smaller.

SUPPLY.

Box elder, including its California variety, has a range of nearly 4,000,000 square miles, which is exceeded by few American trees. In many portions of its extended range, however, the tree is very scarce, and in other regions the growth is too small to be of importance. Here and there box elder timber is put to use, but the total quantity used is very small for a range so large. The species reaches its best development in the valleys of the Wabash and Cumberland Rivers. From Vermont it ranges to Florida, though it is rather rare east of the Allegheny Mountains. It extends west from New England through Canada to the base of the Rocky Mountains on the Saskatchewan River, thence southward along the eastern base of the Rocky Mountains into Mexico. A variety crosses the mountain into Arizona and covers the southern half of California. The tree resembles both ash and maple, and is called ash-leaved maple, cut-leaved maple, negundo maple, black ash, stinking ash, sugar ash, and water ash.

EARLY USES.

It appears that the wood's white creamy color led to its first use for manufacturing purposes. Early in the nineteenth century the makers of mahogany, cherry, and black walnut furniture in the Eastern States employed it for inlay and other ornamentation. The contrast between the white wood of this tree and the dark cabinet woods with which it was associated was all that could be desired. Its color also gave it a place in the early manufacture of dishes and other woodenware. Its habit of growing on fertile land made it the enemy of the first settlers who cleared those lands for farms, and it was cut in comparatively large quantities without being put to any use, except occasionally in the construction of fences or for fuel. It was rather poor material for both.

MANUFACTURING.

With so wide a range box elder is of necessity put to many uses. Anything approaching a complete list of these is hard to procure, for the wood, like many other minor species, loses its name and identity as soon as it reaches the sawmill, and often before the saw log gets out of the woods. It is ash or maple when the furniture factory or the planing mill receives it. If it is considered a maple it is the weakest and least elastic of them all; if it is an ash it does

not compare favorably with other ashes. At the best, it is a rather poor material for manufacturing purposes where strength and stiffness are demanded, but in color it is superior to most of the common white woods.

It is made into interior finish in Michigan, North Carolina, and California. The particular uses for it are as newel posts, stair rails, spindles, capitals, chair boards, and baseboards, occasionally doors and frames, and more frequently flooring.

It is turned to account as handle material, but not where strength and stiffness are essential. Broom handles of this wood present a handsome appearance, and doubtless many thousands listed as maple in the markets are box elder. Woodenware makers draw supplies from this source, and the wood's clear color is its principal recommendation. Ironing boards, sleeve boards, washboards, bread and meat boards, chopping blocks, and the tops of kitchen tables, and shelves for pantries are among the commodities in which box elder gives its best service. Some of it is cut for pulp, but it is not separately listed. It appears in the same way in slack cooperage. It is not believed that the quantity so used is very large compared with some other species, but coopers employ it for numerous wares and in many parts of the country.

The California variety, *Acer negundo californicum*, is generally smaller than the eastern form, and does not serve in as many places because industries are not as varied on the Pacific coast as in the East. The western form differs from the eastern in having wood somewhat heavier, but only half as much ash when burned. It is 50 per cent stronger and 70 per cent stiffer, and is therefore a better wood for vehicles, handles, and for the manufacture of agricultural implements.

VINE MAPLE.

(*Acer circinatum.*)

Vine maple is a western species with a range more restricted than that of the broadleaf or Oregon maple. It is found from the coast region of British Columbia south through Washington and Oregon to northern California. The tree is not of much commercial importance because it is small and rather scarce, but it is put to several uses in parts of its range. Lumbermen make ax handles of it in Oregon, and it gives good service in shovel and small-tool handles. Indians prefer it for fishing net bows. It is not half as stiff as sugar maple. The name vine maple is given this species because of the trunk's habit of lying on the ground. There is small probability that its importance will increase in the future.

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Contribution from the Forest Service, Henry S. Graves, Forester.
February 24, 1914.

WHITE PINE UNDER FOREST MANAGEMENT.

By E. H. Frothingham, *Forest Examiner.*

SUITABILITY OF WHITE PINE FOR MANAGEMENT.

Of all the trees of eastern North America white pine best combines the qualities of utility, rapid growth, heavy yield, and ease of management. Its former abundance and the cheapness and varied usefulness of its lumber made it an important factor in the development of the States in which it grew and even of regions far outside of its natural range. After an enormous and for a long time unapproached exploitation the original forests are now approaching exhaustion, and the large-size high-grade white pine lumber, once abundant on the market, has become scarce and expensive. With its decline, lower grades have come into existence and have found a ready market where large size and high quality are not essential.

The demand for low-grade white-pine lumber has made it possible, from a business standpoint, to cut and market second-growth white pine when comparatively small and young. For many years the pine output of the Northeastern States has consisted almost wholly of second growth, most of it cut in limited tracts or woodlots by small portable mills. Thousands of such stands exist on abandoned farms or pastures in New England. In other regions white pine has sprung up in abundance after lumbering and needs only time and protection from fire to develop into thrifty, valuable stands. Had fires not been allowed to run repeatedly over the slash left in logging the original stands, a large part of northern Michigan and other noted white-pine regions would probably now be covered with pine second growth, much of it already of merchantable value.

Because of the success with which white pine lends itself to management, the relatively steady market, and the small amount of waste in lumbering, there is no doubt that under widely varying conditions of quality and accessibility, and with the prevailing tax rates, market value, and wages, the raising of white pine to ages of from 35 to 70 years is a profitable undertaking at 4, 5, 6, and sometimes 10 per cent compound interest.

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This bulletin summarizes the most important facts relative to white pine, with regard both to the original forest and to the second growth. The yield tables for second-growth stands presented in the bulletin are based on measurements made in southern New Hampshire by C. A. Lyford and Louis Margolin. These may be considered as roughly applicable to second-growth stands throughout most of the range of white pine. From them have been derived tables showing the value of stumpage at prevailing prices and the profit or loss resulting from the management of second growth under favorable and unfavorable conditions. Methods are also suggested for securing successive crops and for increasing the quantity and quality of the yield. The chapters on "Direct Seeding" and "Protection" are from an unpublished report on white pine by A. K. Chittenden and J. S. Ames.

GEOGRAPHICAL RANGE.

White pine grows in general from Newfoundland to southeastern Manitoba; thence southeastward through Minnesota and central Wisconsin, with detached groves as far south as central and eastern Iowa, southern Wisconsin, and northern Illinois; and eastward through southern Michigan and along the northern shore of Lake Erie to New York. It is found in the northeastern corner of Ohio and throughout the Appalachian Mountains as far south as Alabama and Georgia. It is abundant throughout New England, New York, and Pennsylvania, and on the Atlantic coast reaches its southern limit in central New Jersey.

The presence of white pine in this region is doubtless due to the cool, moist climate. The cold climate farther north, the warm one to the south, and the dry one to the west are all inhospitable to white pine because their soils do not supply enough moisture for transpiration. In the North this is due to the low temperature of the soil moisture during much of the year and to low atmospheric humidity, in the West to light precipitation and dry winds, and in the South chiefly to the high temperature and low relative humidity of the air. In the Appalachians suitable climatic conditions exist at increasingly high altitudes as one goes south, so that while in the North white pine is common at sea level in Alabama and Georgia it does not thrive below an altitude of 2,500 or 3,000 feet.

One of the factors responsible for the commercial importance of white pine was its abundance. Thus, while the usefulness of the lumber caused small tracts of white pine or even individual trees to be highly prized in regions where pine was scarce, it was in the dense pineries, and where the tree grew abundantly among hardwoods, that white-pine lumbering assumed importance. The region in which white pine was especially abundant comprised the New England

States, New York, Pennsylvania, the Lake States, and southern Quebec and Ontario south of the "Height of Land."

In New England white pine seldom formed solid bodies of large extent, but usually grew mixed with spruce and other conifers and hardwoods. In several places, however, large pure stands of white pine were found. Great pine forests stretched along the valleys of the Connecticut and Merrimac Rivers and grew along the shores of Lake Champlain in western Vermont.

White pine was abundantly scattered, either individually or in small stands, throughout the hardwood forests of the Adirondack region in New York; was conspicuous along the Hudson River and in the Catskills; and was found on occasional sandy plains or on elevations throughout the broadleaf forests which covered the remainder of the State. In Pennsylvania vast forests of white pine and hemlock covered both flanks of the Allegheny Mountains, and occasional groves existed among the heavy forests of hardwoods and hemlock east and west of the Allegheny region. The headwaters of the Susquehanna River were heavily wooded with white pine.

The densest and most extensive forests of white pine were those in Michigan. As compared with New England the topography there is level, and favorable conditions for the growth of white pine existed over wide areas. It was abundant in the northern part of the lower peninsula, where on the sandy soils it grew in immense practically pure forests, and on the heavier loams interspersed among hardwoods. In the northern peninsula, especially in the basin of the Menominee River, it covered the sandy plains almost to the exclusion of other species.

In Wisconsin there were fewer pure stands of white pine than in Michigan, though some could be found in gravelly or sandy regions in many parts of the State. In mixture with hardwoods and other conifers, however, white pine was very abundant.

The pine forests of Minnesota were confined to the northern and central portions of the State. They were not so extensive as those in Michigan, but, as elsewhere in the Lake States, white pine was very prominent in mixture with hardwoods.

White pine was not abundant in the Southern Appalachians, and the few pure stands were confined to some of the higher moist valleys. In these the timber was often of the finest quality, with dominant trees ranging from 100 to 200 feet in height. Few stands, however, exceeded a cut of 25,000 board feet per acre, and the yield was ordinarily not more than from 2,500 to 5,000 feet. The proportion of good lumber in southern-grown white pine is not as high as in the trees grown in the North.

It has been estimated that the original stand of pine in the Lake States (including Norway pine) amounted to more than

350,000,000,000 board feet. Of this it is stated Michigan had about 150,000,000,000 feet, Wisconsin about 130,000,000,000, and Minnesota about 70,000,000,000. Since lumbering began not less than 250,000,000,000 feet have been cut and perhaps 100,000,000,000 feet burned. In 1880 the census estimate of the stand was less than 88,000,000,000 board feet, but according to the annual reports of the American Lumberman the cut since then has exceeded 170,000,000,000. In 1900 the census estimated the stand at 50,000,000,000, and in 1903 R. A. Long placed it at 60,000,000,000 feet. According to data compiled by R. S. Kellogg, of the Forest Service, the lumber production of all species in the Lake States between 1880 and 1910 was:

Michigan: 103,525,000,000 board feet; about 75 per cent white pine.
Wisconsin: 80,385,000,000 board feet; about 80 per cent white pine.
Minnesota: 44,890,000,000 board feet; about 95 per cent white pine.

Of the total production of lumber in the United States during these 30 years white pine furnished 14 per cent, or 58,000,000,000 board feet.

The amount of privately owned pine (white and Norway) now standing in the Lake States is estimated by the Bureau of Corporations[1] as:

	Board feet.
Michigan	2,000,000,000
Wisconsin	3,200,000,000
Minnesota	12,500,000,000

There is some reason to believe that the total quantity in Wisconsin is understated. The proportion of white pine comprised in the stand, for the States named, is tentatively placed at 79, 83, and 64 per cent. White and Norway pine together formed, respectively, 4.2, 11, and 53.9 per cent of the total stand of timber in the States listed, or a total of about 18 per cent of the Lake States forest. On the basis of these figures the present annual cut of pine is comparatively large. The cut for the year 1909, according to the Bureau of Corporations, took 12.3 per cent of the standing pine in the Lake States: 12.9 per cent of that in Michigan, 19.1 per cent in Wisconsin, and 10.5 per cent in Minnesota. For Wisconsin the percentage may be somewhat too high, since it is based on a very conservative stand estimate.

WHITE PINE AND THE LUMBER INDUSTRY.

The history of white-pine lumbering begins with the first settlement of the country. In 1623 mills were set up in New York, and by 1635 white pine was being exported from New England. At that early date little was known as to the available supply, even in the country close to the shipping points, and in 1650 fears were ex-

[1] Report on the Lumber Industry, Part I, Standing Timber, Jan. 20, 1913.

pressed in New England that the timber would soon be exhausted. For more than two centuries, however, the white-pine forests of the Eastern States yielded an ever-increasing output of lumber. The Louisiana Purchase in 1803 opened up in New Orleans a profitable market for the white pine of southwestern New York and northwestern Pennsylvania, and immense rafts of logs were floated down the Ohio and Mississippi Rivers from the region about the headwaters of the Allegheny.

White-pine lumbering began in Michigan and Wisconsin in the decade between 1820 and 1830, but it was not until after the latter date that any considerable quantity was cut. By 1840 enough was known of the extent of the Lake State pineries to bring lumbermen from the Eastern States, where a shortage of supply was already imminent. For over 40 years the white-pine industry of the Lake States continued to increase in volume until the annual production in Michigan alone reached a total of nearly four and one-half billion feet.

In Minnesota active lumbering did not commence until about 1875, 5 or 10 years before the high mark of the output of Michigan was reached. By 1899 Minnesota stood second to Wisconsin in point of production, while Michigan had dropped to third place. Five years later Minnesota, with a cut of less than 2,000,000,000 feet, was first, and Wisconsin second, a relative position which they have since maintained. With the depletion of its forests Michigan rapidly lost importance as a pine-producing State, and now stands sixth in the list, with an annual cut not one-twentieth as great as in 1883.

In America, with its immense natural forests, the cost of raising timber has not been a factor in determining its value. Heretofore the supply has been relatively large as compared with the demand, and stumpage prices have been correspondingly low. More recently, however, the demand for some kinds of lumber has equaled and sometimes exceeded the available supply, and in some cases stumpage values now even exceed the total cost of raising the timber artificially. An example of a marked rise in stumpage is that of the Wisconsin pine lands purchased by Ezra Cornell in 1866 for 60 cents per acre or equivalent to from 5 to 10 cents per thousand board feet. Of the 500,000 acres thus bought one-fifth was sold in 1873 for $4 per acre, or about 30 or 40 cents per thousand feet. By 1905 practically all the land had been disposed of at a clear profit of nearly $5,500,000. Some of the last sales of stumpage were at prices ranging from $10 to $12 a thousand. Virgin white-pine stumpage may now bring as much as $20 a thousand, and in Wisconsin a stumpage price of $65 per thousand has been paid for selected trees. (See Pl. II.)

Repeated rises in the price of stumpage often led to undervaluation of white-pine stands. In Minnesota, for example, a stand purchased for $30,000 was within a few years refused for lump sums of $50,000,

$100,000, and $150,000, and was finally sold, on a stumpage basis of $2.25 per thousand for large and $2 for small logs (20 logs per thousand feet), for a total of $365,000. In another case the stumpage on a 30-acre tract of second-growth pine in New Hampshire was bought for $1,000. When cut and sawed the pine yielded 530,000 board feet, worth at least $5 per thousand on the stump, or in all $2,650. Such underestimates, often resulting in loss to the owner, are constantly being made. Usually the cause is ignorance either of the amount and quality of the timber or of how to determine its value. Farmers and owners of small woodlands in connection with other property are most likely to lose money in this way.

As might be expected, the decrease in the output of pine has been accompanied by an increase in the value of the lumber. Thus, while the production of pine has fallen off over 56 per cent since 1890, the mill value of the total annual cut has declined only about 35 per cent. The average mill value per thousand feet has increased 50 per cent.

The high-grade white-pine lumber once so widely used in house building and finish is now largely restricted to pattern making, sash and door manufacture, and other exacting uses. White-pine uppers bring $90, $100, and even $130 per thousand board feet. It is probable that these prices mark practically the upper limit for high-grade pine lumber. In the case of the lower grades, however, which comprise much the larger part of the lumber manufactured, prices will no doubt continue to rise as the supply becomes scarcer.

Even the high price of the best white-pine lumber would not, under present conditions, warrant private owners growing trees to the ages necessary to produce these grades. Within the relatively short rotations of 70 years or less, which at present appear to be the only ones under which white-pine management can be made profitable, only grades of moderate value can be produced. Most second-growth lumber is manufactured "round," or bark edged, and disposed of to box and match factories.

In New England, where the timber is practically all second growth, box-board lumber is purchased round edged, usually in thicknesses of $\frac{7}{8}$, 1, $1\frac{5}{8}$, or $2\frac{1}{8}$ inches. The demands of the box manufacturers are extremely moderate. The boards are first cut into box lengths and in the widths involving the least waste of material. Often the boards are tongued and grooved parallel to the bark "wane," which gives them a trapezoidal shape. Widths as small as 2 inches and lengths of 3 and 4 feet are often accepted, if they do not form too large a proportion of the total amount. Box boards $2\frac{1}{8}$ inches thick are resawed in the factory into two 1-inch boards. Box-board lumber usually brings from $14 to $18 per thousand feet f. o. b. local markets, the price varying with thickness and to some extent with quality. One-inch boards, commonly called "sidings," are the least valuable and

rarely bring over $15 per thousand. They are more expensive to handle, and as few as possible are manufactured.

For match blocks clear, straight-grained lumber is required. As in box making, lumber 2⅛ inches thick is the standard for match manufacture. It usually commands a price of $17 or $18 a thousand. Second-growth stands yield a small amount of material clear enough for match bolts. Match companies usually accept 2⅛-inch round-edged lumber without careful grading, and dispose of the material unsuited for match blocks (often 70 or 80 per cent of the total) for boxes.

But little lumber clear and straight enough for sashes and blinds is produced in the average "pasture-pine" stand less than 60 or 70 years old. On good soils, however, the more rapid growing trees may yield clear, straight pieces long enough for the purpose. Such lumber, round edged and 1⅜ or 1⅝ inches thick, may command a price of from $25 to $35 a thousand, provided the clear lengths are 2 or more feet long and the knots small.

Square-edged second-growth pine timber 1 inch thick usually brings from $20 to $25 in the local markets, but the waste and expense involved in edging nearly or quite offset the difference in price as compared with round-edged box boards. The waste in edging is usually from 10 to 20 per cent, since the boards must have parallel edges, while in box lumber a considerable proportion of crooked boards is accepted. One-inch square-edged lumber is comparable to the standard grade of No. 2 common. It usually varies widely in quality.

GENERAL CHARACTERISTICS OF WHITE-PINE STANDS.

OLD GROWTH.

A characteristic of the original white-pine forests which contributed largely to their commercial importance was their great age. The majority of the stands cut were from 200 to 300 years old. The trees in such stands were often from 150 to 200 feet high and from 4 to 7 feet in diameter, and produced lumber of the largest size, practically free from knots and other defects. In 1700, New Hampshire lumbermen were able to supply white-pine planks 25 feet long and 15 and 18 inches wide, and ship-dock material 36 feet long and 3 feet wide. In the Lake States single acres sometimes yielded 75,000 and occasionally 100,000 board feet, and entire "fortys" often averaged 50,000 feet per acre. Townships have been known to yield 400,000,000 board feet, or an average of about 18,000 feet per acre. Such yields were, of course, obtainable only where the forest was pure and practically unbroken, but even in rough country and in stands not exclusively of pine the large size of the individual trees often resulted in high yields.

White pine at one place or another associates with nearly every other tree species native to the Northeastern and Lake States. There are several species, however, with which it shows a special tendency to mix throughout its range or in portions of it. On the better soils hemlock, red spruce, sugar maple, beech, basswood, elm, and yellow birch form with white pine characteristic forest types. Hemlock is perhaps the most common associate throughout its range. Of slower growth, smaller size, and more shade enduring than white pine, it often forms a dense under-story of foliage beneath the pine crowns. Under the heavy shade of such stands the forest floor is absolutely bare, save for the thick layer of decomposing needles. In the early logging operations, which removed only the best of the pine, hemlock was considered valueless, except where tanbark markets existed, and was left standing. Even the felled trees from which bark had been removed were left to rot in the woods. With the disappearance of the pine, however, hemlock lumber has steadily increased in value.

On the deep, loamy soils where white pine associates with hemlock, maple, beech, and birch the white pine reaches its best individual development (Pl. I). Lumbermen early removed the white pine, and later in some places the hemlock from these stands, leaving the hardwoods in possession of the soil. Hemlock seedlings often persisted in the hardwood forest after the removal of the mature trees, but except in large openings the young white pine succumbed to the shade.

In the Northeastern States red spruce, which itself forms immense, practically pure stands, was also a common associate of white pine in the original mixed hardwood forest. Both spruce and pine have been largely culled, and while spruce seedlings are often abundant under the hardwood crowns, pine seedlings are rare. In aspen and paper birch stands, however, where the light foliage casts but little shade, young white pine and other conifers often grow in abundance, and eventually take the place of the short-lived birch and aspen.

On dry, sandy soils in the East, white pine often grows mixed with pitch pine, and in the West with Norway pine and jack pine. Both Norway and jack pine reach their best development in the Lake States and in Canada, where they form large pure stands on soils too dry for white pine, associating with the latter on slightly moister ones. The white and red pine mixture is especially important. Typical pine forests on fresh, sandy soils in Michigan consisted of white pine (45 to 55 per cent), red pine (25 to 45 per cent), with scattering hemlock (10 to 15 per cent), and occasional fir and hardwoods. Red-pine lumber is not much inferior to white pine, and large quantities are mixed with and marketed as the latter. Jack pine is so small and limby that until recent years it was considered valueless.

In the Southern Appalachians hemlock was the principal associate of white pine in the valleys, while on the drier slopes and ridges the latter usually grew in mixture with oaks, chestnut, and other hardwoods.

Throughout the early history of white-pine logging there was little demand for any except the finest grades of lumber, and the amount of loss involved in supplying these was enormous. Only the best logs from the best trees were taken, and of these as much as one-half was often lost in slabs. In fact, it was claimed that it took four trees to produce the amount of lumber contained in one. Labor was a very large, and stumpage value a very small, item in the cost of sawed lumber.

Even when this waste is considered, it is probable that the drain upon the forest by lumbering was less than half that involved through loss by fire. The dry, resinous slash of pine branches and leaves left after logging was almost sure sooner or later to become ignited. The hot fire from this not only consumed the scattering trees left on the cut-over areas, the seeds from which might have restocked the land with young growth, but also spread to adjoining timber. In this way countless acres were burned and reburned, until the ground was bare of mature timber, young growth, and even of the rich forest soil of decaying leaves and litter. Thus by destroying whatever seed trees and young growth lumbering had left, fire made it impossible for the forest to reproduce itself.

Though white pine often grew in places more valuable for agriculture than for the production of timber, the forest was removed from many situations either too steep and broken or too sandy and poor for agricultural use. The value for timber crops of such regions as the great sand plains of Michigan and the sandy areas of Wisconsin, and the mountains of Pennsylvania, is demonstrated by the quality of the white-pine stands which once grew there. With efficient protection from fire there is no reason why these regions can not again be made to produce pine.

SECOND GROWTH.

Stands which come up naturally after lumbering or fire are called second growth. In second-growth stands growth is vigorous, while in very old stands it is nearly if not quite balanced by decay. Overmature stands, being unproductive, represent idle capital, and the best use of the land demands their replacement with rapid-growing, productive stock. This, in fact, was what actually followed the logging of white-pine forests where fire did not later run over the ground. In Wisconsin there was estimated to be in 1897 about 200,000 acres of second-growth white-pine thickets which had sprung up in the previous 25 years.

In New England, where nearly all the original growth was removed many years ago, and where fires have as a rule been less destructive than in the Lake States, the lumber industry has already drawn heavily upon the second growth. Within recent years the cut of pine, which, in 1910, amounted to nearly 670,000,000 board feet, has been almost wholly of lumber from second-growth stands. This, of course, is much inferior to that from the original forests, chiefly because it is knottier, smaller, and has a larger proportion of sapwood; yet its usefulness for box boards and other purposes which do not demand large, clear stuff makes its aggregate value to New England but little below that of spruce. A large proportion of the young pine in New England has come in on abandoned farm lands, which in the aggregate embrace a very large area. These lands, which have proved themselves at least temporarily worthless for cultivation, are especially adapted to the growth of the tree. Cleared land, subsequently cultivated, presents ideal conditions for the germination of white-pine seed, and when a sufficient number of seed trees are near the area a dense, even-aged stand of white pine is almost sure to take possession of the ground. The growth of such stands is so rapid, their management so simple, and their yield under short rotations relatively so great that, for second growth, white pine is in many cases superior to any other species. A certain percentage of valuable hardwoods, such as white ash and black cherry, add considerably to the value of the stand, not only because of the high value of their wood, but also because when growing with them white pine produces clearer trunks, smaller branches, and is less likely to be damaged by weevils than when growing pure. Less valuable hardwoods, such as red maple, may serve a similar purpose. Gray birch, however, which in New England often associates with white pine, is distinctly undesirable in mixture with it. The slender stems of the birch, which commonly grow in clumps from a single stump, spread out widely, and when swayed by the wind are likely to damage the upper branches and tender tops of any small pines within their reach. Often a number of otherwise healthy young pines will be killed outright by a single clump of birches. (See Pl. III, fig. 2.)

SILVICAL CHARACTERISTICS.

Silvical characteristics embrace the soil, moisture, and light requirements of a species and its reproductive and growth characteristics.

SOIL AND MOISTURE REQUIREMENTS.

Broadly speaking, all the tree species in a given region require for their best growth much the same physical characteristics of the soil. In general, soils 3 or 4 feet deep, which are porous and well-drained but capable of holding sufficient moisture during dry seasons, are the

best for all trees. Where the species differ is in their ability to thrive under less favorable conditions. In the North woods, for example, maple, beech, and hemlock need better soil conditions than white pine and do not thrive well enough on poorer soil to compete with it. White pine also grows best in deep, fresh, loamy soils, and the largest white pine trees were found scattered among the hardwood forests on such sites. The heavy shade cast by the broadleaf trees, together with their capacity, not shared by the pine, to sprout abundantly when cut or burned down, made it impossible for white pine to monopolize the best soils, and its forests were found, therefore, in drier and less fertile situations. Sand is the principal constituent of the soils on which grew the best white pine forests. The deeper, moister, and more loamy the sand the better are the trees developed. By its rapid growth on such soils the pine is able to exclude slower-growing species like hemlock, beech, and maple, and more light-needing trees like red, pitch, and jack pine. The last three species are less exacting than white pine, and will form forests on soils too dry for the latter. On the other hand, white pine is often found in poorly drained, somewhat swampy situations, in company with fir, arborvitæ, tamarack, and other swamp-inhabiting species. In such places, however, its growth is apt to be relatively slow.

Compared with the size of its trunk and crown, the root system of white pine is small. There is no taproot, but three or four stout roots grow downward slantingly, and in time give the tree a firm hold on the soil. On shallow soils with impervious hardpan or underlying rock strata the roots spread out close to the surface; in deeper soils they penetrate downward for 3 or 4 feet. Growth is less vigorous on shallow than on deep soils, because the former more quickly lose their moisture.

Tree leaves give up daily to the air great quantities of water, which the roots have absorbed from the soil. The more foliage a tree has the larger and more active must be its root system. Since the amount of light received by a tree directly influences the amount of its foliage, it must also influence the development of the roots. Thus, pine trees which grow in the open and have heavy foliage also possess deep and extensive root systems, while those in dense stands and with little foliage may have deep but rarely large or extensive roots.

LIGHT REQUIREMENT.

Light is the agency by which plant leaves manufacture food for the tree out of water drawn up through the roots and carbon dioxide obtained from the air. The amount of light necessary to sustain life, however, varies with different species. Compared with other trees, white pine may be classed as intermediate in its light require-

ment. It succumbs to shade much more quickly than hemlock, spruce, beech, or maple, but needs less light than red, pitch, or jack pine, gray birch, or aspen.

The less light a tree receives the slower will be its growth, and if shaded beyond a certain point it will die, practically from starvation. A suppressed tree to which light is admitted will respond in a greater or less degree, according to the length of time it has been suppressed, by putting forth new foliage and increasing its rate of growth. White pine does not possess the power to recover from suppression to the extent shown by hemlock, spruce, or fir, which will exist for years under heavy shade, and then, with the admission of light, spring at once into rapid, vigorous growth. If not too long suppressed, white pine will usually recover to some extent when released, though its subsequent growth is apt to be less thrifty than that of unsuppressed trees.

The trees more tolerant of shade naturally produce more foliage and themselves cast more shade than those less tolerant, and it is for this reason that white pine seedlings under maple, beech, hemlock, or even heavy white pine crowns, can not grow. Under the light shade of aspen, paper birch, or other intolerant trees young white pine often receives just enough light to keep it alive and to stimulate a rapid height growth, which results if the soil is good enough, in its eventually overtopping and displacing the other species. When mixed with heavy foliaged hardwoods or hemlock white pine crowns almost always project above the general level of the crown cover. In such stands the pine is able to reproduce itself only when its seeds fall in chance openings large enough to admit full light during the period necessary for the tops of the young trees to reach the level of the crown cover.

Since white pine is more tolerant of shade than is red pine it is able to grow in much denser pure stands and hence will produce a greater amount of wood per acre.

FORM.

Young white pines have a symmetrically conical form, due in large part to the fact that the branches grow in whorls. A whorl of branches marks each season's growth, so that two contiguous whorls afford a means of determining the height growth for a given year, and all the whorls together the approximate age of the tree. Each successive whorl shuts off light from the ones beneath, and these must increase in length if they are to continue to function. In the stand this increase is checked by the branches of adjacent trees, while in the open it is limited only by natural forces, chiefly gravity. In consequence, the crowns of open-grown trees are often broad pyramids reaching close to the ground.

A WHITE PINE TREE, PROBABLY 250 YEARS OLD, IN A VIRGIN FOREST OF THE HARDWOOD AND HEMLOCK TYPE.

[Note the clear, cylindrical trunk, as compared with the branchy, tapering stem of the adjacent dead hemlock.]

HEWED PINE TIMBERS FOR SHIPMENT TO ENGLAND.

[Two or three centuries are needed to produce timbers like these, the stumpage value of which is now $65 per thousand board feet. Menominee Indian Reservation.] (Photograph furnished by Mr. N. L. Dowling.)

In dense young stands most of the lower branches die from shade, growth is largely concentrated in the tops, and height growth is therefore rapid. Since the amount of food manufactured by the tree is proportionate to the amount of foliage, which in dense stands is small, wood is produced very slowly, and diameter growth is correspondingly slow. Thus while trees in the open are relatively short, with thick trunks and large, branching crowns, forest-grown trees are tall, with long, slender trunks (comparatively free from large branches if in mixture with hardwoods), and relatively short and narrow crowns. An open-grown tree actually contains more wood than a forest-grown tree of the same age, but its value, volume for volume, is much less. The difference lies not only in the better form of the forest-grown tree, but also in the actual structure of its wood, which contains more thick-walled mechanical tissue and less thin-walled water-conducting cells than that of open-grown trees.

In fully stocked sapling and pole stands, the stems are straight, slender, tapering, and smooth barked, with numerous whorls of small branches. At the end of this period the live crown is usually confined to the upper two-thirds of the stem. As the tree matures the bole becomes more cylindrical, and the crown loses its regularity and compactness. A characteristic defect of white pine, from a commercial standpoint, is its retention of dead branches, which causes the lumber to be knotty. In dense stands the branches, and consequently the knots they leave, are smaller than in the case of open-grown trees. Moreover, when in mixture with hardwoods, the slender dead branches are readily broken off by the swaying limbs of the broadleaf trees. The exceptionally clear boles of the virgin white pine which grew in dense hardwood forests were undoubtedly the result both of the shading and death of the branches while still small, and of the mechanical breakage of the small branches by the impact of spreading limbs of near-by trees. (See Pl. I.)

When white pine grows on the thin soils of ridges at high altitudes it produces a short and rapidly tapering trunk, while the crown, if exposed to severe winds, is likely to be distorted. One of the first considerations in planting white pine should be the quality of the site, since upon this depends the rate of growth and also, to some extent, the form which the trees will have.

The classification of trees according to the number of logs they will yield, practiced by timber estimators, illustrates the practical importance of form in determining the value of trees. Foresters have carried this still further, and on the basis of thousands of measurements of felled white pines have determined the average contents in board feet and cubic feet of trees of all the forms and sizes ordinarily found. Such figures are given in the volume tables (pp. 64–68).

REPRODUCTION.

Where it is planned to raise successive crops of trees, a comparative study of the methods of reproduction is important. The best and most economical means of reproduction are the natural ones afforded by the stand itself, provided these can be relied upon. Artificial methods are expensive, and require considerable technical skill in carrying them out. On the other hand, since they do not require the presence of trees to seed the area, a free choice of seasons and sites is possible. With plantations the element of uncertainty which surrounds natural reproduction is avoided.

The abundance and thrift of the second growth white pine on pastures and abandoned farms in the Northeast show that under proper conditions white pine can reproduce itself excellently by natural means.

SEED PRODUCTION.

The production of seed, like that of wood, depends upon the amount of food which the leaves manufacture. With other conditions equal, the more light a tree receives the earlier and more abundantly will it bear. Thus full-crowned, open-grown trees will begin to bear earlier and will produce more seed than small-crowned forest trees of the same age and on the same kind of soil. Seed production is also earlier and more abundant on good soils than on poor. With plenty of light, white-pine saplings begin to bear cones when less than 20 years old. As a rule, however, seed are not produced in abundance until the trees are from 35 to 70 years old, depending upon the amount of light received. As the trees increase in age they bear more prolifically, and the proportion of fertile seeds increases. With the decline in vigor which attends old age there is probably a corresponding decline in the amount and quality of seed produced, but white pine continues to bear fertile seed in abundance for at least 200, and probably 300, years.

White pine cones require two years to mature. They begin to form in June, and by the fall of the first year reach a length of 1 or 2 inches. Thus it is possible to tell a year in advance whether or not there will be a heavy seed crop. The cones reach their full length—5 to 11 inches—early in the summer of the second year, and open in the fall, usually in September. A frost sufficiently severe to kill squash vines will often cause mature cones to open. Each cone bears from 50 to 75 oval seeds—two on the upper face of each scale—about one-fourth of an inch long, and equipped with thin, membranous wings. A bushel of cones will yield from one-half pound to a pound of cleaned seeds, which run from 26,000 to 30,000 to the pound.

Heavy crops of seed are borne at intervals of from 3 to 7 years, with occasional intervening years of lighter production. The same year

may not mark a heavy seed production over the entire range of white pine, and a "seed year" may occur in some localities simultaneously with an "off year" in others. Local conditions of soil and climate have great influence on the frequency of seed years. Scarcity of water stimulates seed production in most plants, and it is quite possible that fluctuations in soil moisture may have some influence on the frequency of seed years of white pine.[1] In off years not only is less seed produced, but the ravages made upon the supply by birds and rodents is more keenly felt. Insect damage, too, is concentrated, so that a small crop is likely to be one of low quality as well. Even in off years, however, seed production in some localities may be fairly plentiful.

The relatively long intervals between seed years put white pine at a disadvantage, compared with trees which bear heavy crops more frequently. Several of the broadleaf species bear seed abundantly each year, and when these are shade-enduring trees with heavy crowns they are often able, in company with underbrush, completely to cover a cleared area, and so prevent white pine from obtaining a foothold. In the Lake States, jack pine, which nearly every year bears abundant crops of small, winged, fertile seed, is able to monopolize cleared areas, practically to the exclusion of white pine.

Seed Distribution.

The chief agent of distribution of white pine seed is wind. Trees standing on high, windy slopes and ridges may shed their seeds to a distance of half a mile, or even more, over the adjoining lowland. In valleys the range of seeding is very much less. On level land the distance to which seeds will be carried in any number, when unobstructed by crowns of other trees, is usually between 100 and 200 feet. Reproduction, of course, is densest and most even-aged near the mother trees. Where abandoned fields or pastures adjoin white pine woodland, dense even-aged stands of pine are almost sure to develop, the stand becoming more open as its distance from the seed supply increases. When seed trees are left well distributed on a cut-over area, a fully stocked, even-aged second growth may often be established after one or two full seed years (Pl. IV, fig. 2). When seed trees are scarce or poorly distributed, complete restocking may require a much longer time, or the result may be that other species, possibly undesirable ones, will come in with the pine. From 5 to 10 good seed trees per acre are usually sufficient to give a close, even-aged stand of second growth. The number should never be less than 3 or 4, selected with reference to the direction of the prevailing wind.

[1] Height and Dominance of the Douglas Fir, by T. C. Fry. Forestry Quarterly, vol. 8, No. 4, p. 467.

GERMINATION OF SEED AND GROWTH OF SEEDLINGS.

When fresh, from 70 to 90 per cent of white-pine seeds are fertile, and under favorable conditions will germinate. With unfavorable conditions, however, the mortality is very great. Much of the seed, either while in the cone or after it falls to the ground, is consumed by birds and rodents. Of the seeds which escape destruction by animals, many die through falling on unfavorable sites. After germination seeds need, for example, a certain amount of moisture, though too much will cause them to decay. Seeds which fall during dry seasons may lie dormant until the next year, provided they are not destroyed in the meantime. When properly stored, white-pine seeds can be kept for five years or more without great loss, but under natural conditions it is probable that only a very small proportion ever germinate after the second spring following their ripening. Quantities of pine seed are destroyed by forest fires, which may burn the cones on the trees or destroy the seed after it has fallen. When drought and forest fires follow the falling of seed during an off year, nearly the whole of the crop may be lost.

Germination takes place, as a rule, in the spring, and in practically every kind of soil with sufficient heat and moisture. If the young seedling is to live, its roots must soon find the mineral soil. Young plants which spring up on insufficiently decomposed leaf litter are almost sure to die.

Seedlings thrive in soil which is at once moist, porous, and well drained. Sandy or loamy soils, well mixed with decayed organic matter, and protected by vegetation or leaf litter, meet these requirements. Should the soil dry out even to the slight depth to which the roots of the seedlings have penetrated, a great many of the young trees will die.

To determine the effect of moisture conditions upon the death rate of seedlings during the first two years of life, nine sample plots were marked out in 1909 near Petersham, Mass., in dry, fresh to moist, and wet situations. The dry situations were either entirely unshaded or only partially shaded by underbrush, and had from 2 to 3 inches of pine or else from 4 to 5 inches of broadleaf litter. The fresh to moist situations were well drained, lightly shaded, some bare of pine litter, and others with a cover up to 3 inches in depth. The wet situations were low, poorly drained bottom lands on which water stood during a part of the spring. The average number of seedlings on the plots in 1909 was: In the dry situations 29, in the fresh to moist 60, and in the wet 14. When counted in 1910 the proportion still alive in the dry situations was 53 per cent, and in the fresh to moist 86 per cent, while in the wet none had survived.

As long as the young roots extend but a few inches into the ground the character of the subsoil makes little difference; but as the roots

FIG. 1.—WHITE PINE PRUNES ITSELF POORLY WHEN GROWN IN PURE STANDS.

FIG. 2.—WHITE PINE SAPLINGS ENDANGERED BY GRAY BIRCH AND IN NEED OF A DISENGAGEMENT CUTTING.

FIG. 1.—A 60-YEAR-OLD WHITE PINE STAND IN WHICH A REPRODUCTION CUTTING WAS MADE THREE YEARS AGO.

[This resulted in an abundant reproduction of both white pine and white ash. Because of its slow growth when very young the pine has little chance of success in competition with the ash, and the latter should be favored.]

FIG. 2.—WHITE PINE REPRODUCTION, FILLING A CUT-OVER AND BURNED SPACE IN A HARDWOOD FOREST.

[Pine seed trees in the background.]

penetrate into it the subsoil becomes more and more important in the growth of the tree. Its roots once well established in fertile, moist soil, future growth of the seedling depends very largely upon the character of the vegetation surrounding it. In hot, exposed situations it needs, during the first summer, a slight protection from the intense heat and light of the sun. On old fields and pastures this is afforded by short grasses and low scattered herbaceous vegetation, like sweet fern and blueberry. A light cover of ferns or other small herbs will often cast just enough shade to protect the pine seedling, yet afford it sufficient sunlight with which to manufacture food.[1] On the other hand, white-pine seedlings grow so slowly during the first four or five years that they are very easily killed by tall, dense, vegetation of any kind, such as berry bushes, golden rod, fireweed, fern brakes, or rank wild grasses. Not only does such vegetation keep out needed light, but its roots take from the soil the moisture which the young white pine requires. Under the protection of young, fast-growing hardwood sprouts, witch hazel, dogwood, and similar undergrowth, white-pine seedlings may thrive for a year or two, but the shade of such stands is usually too dense for continued growth of the pine (see Pl. III, fig. 2, and Pl. IV, fig. 1). In stands containing broad-leaf trees many white-pine seedlings are smothered by fallen leaves.

To determine the influence of different degrees of shade upon the vitality and rate of growth of white-pine seedlings a number of sample plots were laid out in 1905 at Keene, N. H., in stands of different crown density, but in other respects alike. Table 1, based on counts in 10 plots of 1 square rod each, shows the average size and number of seedlings per square rod in 1905 and the number and size of those still alive in 1909.

TABLE 1.—*Vitality and rate of growth of seedlings under different degrees of shade.*

Crown cover.	Average number of seedlings per square rod.		Per cent living.	Average height.		Average growth in 4 years of seedlings which survived.
	1905	1909	1909	1905	1909	
				Inches.	*Inches.*	*Inches.*
Dense	271	15	5.5	1.5	4.5	3.0
Broken	102	62	60.8	1.5	10.0	8.5
Open	100	94	94.0	1.5	11.0	9.5

GROWTH OF INDIVIDUAL TREES.

An important characteristic of white pine is that its growth is steady and uniform up to an advanced age. In this it differs from all the other eastern and many of the western pines, in which the rate

[1] Influence of Shade and Other Factors on Plantations, by G. W. Kimball and E. E. Carter. Forestry Quarterly, Vol. 11, No. 2, p. 176.

of growth decreases rather abruptly when the tree is still far from decadence. Red pine, for example, has a fairly uniform and rapid growth until about 100 years old, when a marked falling off occurs, the tree growing at a slower rate until its death 100 or 200 years later. Jack pine exhibits a similar trait, though its period of rapid growth ceases very much earlier than that of red pine. It is this habit of sustained growth which gives white pine its great size as compared with the two other species.

The rate of growth varies with the age of the tree, the amount of light received, and the fertility of the soil in which it grows. In general, growth is more rapid on good soils than on poor, and in youth than in old age. The period during which growth is most rapid comes earlier when the tree is favorably situated than when it grows on poor soil.

Growth in Height.

White-pine seedlings grow very slowly, and few of them reach a height of more than a foot during the first 5 years. For the first 3 years annual growth is little more than an inch. Thus 1, 2, and even 3 year old seedlings are so inconspicuous that they are likely to be overlooked, especially when among grass or weeds. During the following two seasons, when rapid growth commences, the top shoots of the seedlings appear everywhere, giving the impression that they have sprung up in a single year.

The height growth of seedlings for the first 10 years under average conditions is shown in Table 2. In a nursery or under specially favorable circumstances the rate of growth may be much faster, while under partial shade it will be slower.

Table 2.—*Height growth of white-pine seedlings.*[1]

Age.	Height.	Age.	Height.
Years.	*Inches.*	*Years.*	*Inches.*
1	1.0	6	17.0
2	1.5	7	24.0
3	3.5	8	32.0
4	7.0	9	45.0
5	11.0	10	64.0

On good, moist soils height growth is most rapid at about the fifteenth year, when it often exceeds 3 feet annually. On poor, dry soils, however, the maximum may not occur before the fortieth year, and then not equal the growth on good soil. From the time when the growth culminates its rate gradually decreases until toward the end of the second hundred years it amounts to only 2 or 3 inches per year.

[1] From measurements of 1,600 young trees. Table from "Natural Replacement of White Pine on Old Fields in New England," by S. N. Spring.

Height growth is also influenced by the amount of light which the tree receives. It is most rapid when the upper part of the crown alone receives a full supply. In open-grown trees, which receive light from all sides, the growth energy is distributed over many large branches, and height growth culminates early, so that the tree remains relatively short, stout, and branchy. On the other hand, if the trees grow so closely together that the crowns are small and crowded, the rate of growth will again be slow.

It is thus evident that trees of the same age and growing in the same situations may vary somewhat in the rate of growth, according to their nearness to one another. This difference, however, is much less than that caused by a marked difference in the quality of the soil. Height growth is, in fact, commonly considered the most reliable single indication of site quality.

Since ordinarily only one whorl of branches is produced in a single year, the age of young to moderately old trees can usually be determined roughly by counting the number of whorls or the scars left by them. When these are absent close to the ground it is necessary to estimate the period which the tree required to grow to the height of the first visible whorl. For rough age determination it will usually do to assume that it took 10 years to reach breast height.

Growth in Diameter.

Growth in diameter takes place through the formation of the thin, concentric layers of wood, commonly called annual rings. With very rare exceptions only a single ring is formed each year, so that the number and width of the rings are a safe guide in determining the age and rate of growth of the tree. To determine the precise age it would be necessary to cut the tree at or within an inch of the surface of the ground, since only in this way can the first year's growth be included. Naturally, the further up the tree the section is cut, the less will be the number of rings, and the amount of this difference is the number of years it has taken the tree to reach the height of the cross section. It is customary to express growth in terms of the diameter breasthigh, since on standing trees this is the point at which the diameter is usually measured.

Like growth in height, the diameter growth of white pine reaches its maximum early in life, and then slowly decreases. It is more persistent than the height growth, however, and continues at a moderate rate long after the former has practically ceased. Trees 60 or 70 years old may still be growing fairly rapidly in diameter.

Diameter growth is slowest when the light supply is barely sufficient to keep the tree alive, and most rapid when the tree grows with its crown in full light and produces a heavy foliage. On dry soils or where there is deficient air moisture diameter growth, like height growth, is slow. This is true also of swampy soils.

Growth in Volume.

Growth in volume is the product of growth in both height and diameter, and is influenced, moreover, by the shape of the tree. In white pine its rate becomes rapid after the period of rapid height growth has passed, and persists to an advanced age, gradually becoming less, until in old age it is more than offset by decay. Like that of diameter growth, the rate is more rapid in the case of open-grown trees with large crowns than in forest trees with small crowns, though, as previously mentioned, the wood produced is less valuable.

Along with the growth in volume there proceeds an increase in quality. This takes place partly through the mere increase in the size of the lumber which can be sawed out and partly through the increase in freedom from knots. White pine holds its branches so tenaciously, however, that, unless pruned, little freedom from knots can be expected before the fiftieth year. The quality of the timber is further improved by the conversion of the soft sapwood into heartwood, which goes on somewhat irregularly as the diameter increases.

GROWTH OF STANDS.

The development of a white-pine stand is a continued struggle between the trees for light and growing space. This struggle commences when the branch tips of the seedlings begin to touch and interfere with each other, and is most acute during the early period of rapid height growth. Success of individual trees in the competition is determined by their ability to make rapid height growth, and so to keep their crowns in the light. As the less vigorous trees fall behind, they become more and more shaded by their thriftier neighbors, and finally die. The mortality from crown competition gradually decreases from the early period of vigorous growth, until at the time the trees have reached full size it is very small. The decrease in the number of trees, however, is more than made up by the size of the survivors. This is shown in Tables 3 to 5, where, even when the decrease in the number of trees is most rapid, the aggregate basal area, breast high, and volume per acre continue to increase—rapidly in first-quality and slowly in third-quality stands.

The difference in height and crown vigor which this struggle brings about makes it possible to classify the trees of a stand in the following way: (1) *dominant* trees, which have full and vigorous crowns and in general overtop their neighbors; (2) *codominant*, those with narrower crowns, which are beginning to fall behind the dominant trees in height growth; (3) *intermediate*, shorter trees, closely crowded by their neighbors and receiving light only from above; (4) *suppressed* trees, those which are shaded from above as well as from the sides, and which will soon die; (5) *dead*, trees which have finally succumbed to shade.

The rate of growth of the stand is influenced by the same physical factors which control that of the individual tree. Computations of future yield must, therefore, take into account conditions under which the trees grow, and it is customary to classify stands according to their height growth, which, as previously said, is the best indicaton of the quality of the site. Quality I shows the most rapid growth, and quality III the slowest.

Stands fully stocked, that is, those which contain just enough trees to utilize all the growing space and to produce well-formed trunks, are said to be "normal." Too many trees result in slender-stemmed, slow-growing stands; too few do not fully utilize the growing space, and produce limby stands of relatively low value. Since growth is more rapid and competition more keen in good situations than in poor ones, the number of trees is less and their size greater in fully stocked quality I stands than in quality III stands of the same age and type.

YIELD OF SECOND-GROWTH WHITE PINE.

The yield of a stand, that is, the amount of wood produced per acre, in large measure determines the choice of species or of material to be produced, the length of rotation, and other important features of management. Volume growth of a stand depends, of course, upon the height, diameter, and volume of the individual trees, and also upon the number of trees.

Tables 3 to 6, which give the yield per acre of three qualities of second-growth white pine, are based upon the results of measurements of 196 typical fully stocked second-growth stands in New Hampshire, by C. A. Lyford and Louis Margolin of the Forest Service.[1] The tables are for use either as guides in predicting the future yield of young second-growth or for determining the present yield of existing stands.

TABLE 3.—*Yield per acre in cubic feet, quality I.*

Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.	Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.
Years.	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*	*Years.*	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*
10	7.2	1.7	1,728	29	800	60	85.5	12.8	311	278	10,500
15	14.5	2.9	1,520	68	1,400	65	90.5	13.7	279	286	11,300
20	24.5	4.0	1,322	115	2,100	70	94.5	14.7	249	293	11,900
25	34.5	5.2	1,115	162	3,000	75	98.0	15.6	226	300	12,500
30	44.0	6.4	879	196	4,000	80	101.5	16.5	207	307	13,000
35	53.0	7.5	710	218	5,200	85	105.0	17.4	190	313	13,500
40	61.0	8.6	583	235	6,500	90	108.0	18.2	177	319	14,000
45	68.0	9.7	485	249	7,700	95	110.5	19.0	165	324	14,400
50	74.5	10.8	408	260	8,800	100	113.0	19.8	154	330	14,700
55	80.5	11.8	354	269	9,700						

[1] Tables based on these measurements have already been published in the biennial reports of the Forestry Commission of New Hampshire for 1905–6 and 1907–8. The present tables differ from the others in that the separation into quality classes is made upon the basis of the height of the dominant trees instead of that of the yield itself.

TABLE 4.—*Yield per acre in cubic feet, quality II.*

Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.	Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.
Years.	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*	*Years.*	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*
10	6.0	1.4	2,015	20	650	60	74.5	10.7	397	248	8,500
15	12.0	2.2	1,834	50	1,150	65	79.0	11.6	348	255	9,200
20	19.5	3.2	1,626	90	1,750	70	83.0	12.4	311	261	9,840
25	28.0	4.1	1,420	131	2,420	75	86.5	13.3	277	267	10,400
30	36.5	5.1	1,192	169	3,250	80	90.0	14.1	251	272	10,930
35	44.5	6.1	950	193	4,180	85	93.0	14.9	229	277	11,400
40	51.5	7.1	760	209	5,130	90	95.5	15.7	210	282	11,850
45	58.0	8.0	633	221	6,100	95	98.0	16.4	195	286	12,250
50	64.0	8.9	537	232	7,000	100	100.0	17.1	182	290	12,630
55	69.5	9.8	460	241	7,800						

TABLE 5.—*Yield per acre in cubic feet, quality III.*

Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.	Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.
Years.	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*	*Years.*	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*
10	4.0	1.0	2,408	14	530	60	64.0	8.6	543	219	6,530
15	9.0	1.6	2,234	33	900	65	68.0	9.4	465	224	7,160
20	14.5	2.3	2,060	60	1,350	70	71.5	10.1	412	229	7,760
25	21.0	3.1	1,886	98	1,850	75	75.0	10.9	361	234	8,320
30	28.5	3.9	1,676	139	2,450	80	78.0	11.7	318	238	8,820
35	36.0	4.7	1,400	167	3,100	85	81.0	12.4	288	242	9,300
40	42.5	5.5	1,118	183	3,780	90	83.0	13.2	258	245	9,750
45	48.5	6.3	900	194	4,500	95	85.5	13.8	239	248	10,150
50	54.0	7.0	764	204	5,200	100	87.0	14.5	219	251	10,530
55	58.0	7.8	639	212	5,870						

Although only fully stocked stands were selected as a basis for the tables, the field data were further narrowed by choosing only those which came nearest to the average degree of stocking. As a means of making the selection the total basal area per acre of the sample plots—that is, the aggregate cross-section area at breast height of all the trees, expressed in square feet—were plotted on cross-section paper according to age and quality and an average curve drawn through the points representing each quality class. All the sample plots in each class which deviated from the average by more than 10 per cent were considered abnormally stocked. Cubic-foot yields given in the tables were computed by means of Table 26, Appendix.

The lumber yields given in Table 6 are the graphical averages of the individual sample plot yields obtained by means of the board-foot volume table 24 on page 66, which is based on the actual saw cut. All trees over 5 inches breast high were scaled.

TABLE 6.— *Yield per acre in lumber of even-aged second-growth white-pine stands.*

Age.	Lumber yield per acre.			Age.	Lumber yield per acre.		
	Quality I.	Quality II.	Quality III.		Quality I.	Quality II.	Quality III.
Years.	*Board ft.*	*Board ft.*	*Board ft.*	*Years.*	*Board ft.*	*Board ft.*	*Board ft.*
20	4,500	.....	.....	65	65,100	51,600	38,100
25	8,400	5,400	.....	70	69,900	56,100	42,300
30	13,900	9,600	5,300	75	74,100	60,200	46,300
35	22,500	15,900	9,300	80	77,850	64,000	50,100
40	32,800	23,500	14,200	85	81,400	67,500	53,700
45	41,800	30,600	19,200	90	84,800	70,900	57,000
50	49,100	36,600	24,100	95	88,000	74,000	60,000
55	55,000	42,000	29,000	100	91,200	77,000	62,800
60	60,200	46,900	33,600				

In using the yield tables it should be borne in mind that, since they are based upon fully stocked stands, they represent better conditions than usually exist in natural stands except over small areas. For this reason, and also to allow for crooked and defective trees, it is advisable to discount the values given by an amount suggested by the conditions in each individual case. A discount of from 10 to 15 per cent of the board-foot yield will usually be ample.

The rate at which average stands increase in volume may be easily determined from the yield tables by dividing the yield at any desired age by the number of years. The average annual growth thus obtained is of use in comparing the rate of growth of stands of different ages or in contrasting the growth of stands of the same age but in different qualities of site. Table 7 gives the average annual growth in cubic and board feet at 5-year intervals for average stands of three qualities. The point where growth culminates (indicated in the table by heavy figures) in general occurs earliest in the best sites. Therefore to secure continuously the greatest yield from successive crops of white pine, the final cutting would have to be made at an age when the average annual growth is greatest. That this age does not always coincide with that at which the money income is greatest is brought out under "Rotation," page 36.

TABLE 7.—*Average annual growth per acre, by quality classes.*

Age.	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.
Years.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Board ft.*	*Board ft.*	*Board ft.*
10	78	65	53	.....	.....	.....
15	93	77	60	.....	.....	.....
20	108	88	68	225	.....	.....
25	120	97	74	336	216	.....
30	135	108	82	463	320	177
35	150	119	89	643	455	266
40	163	128	95	820	588	355
45	171	136	100	929	680	427
50	176	140	104	982	732	482
55	**176.4**	**141.8**	107	1,000	764	527
60	175.8	141.7	109	**1,003**	782	560
65	173	141.5	110.1	1,002	794	586
70	170	140.6	110.8	999	801	604
75	167	139	**110.9**	988	**803**	617
80	163	137	110.3	973	800	626
85	159	134	109.4	958	794	632
90	155	132	108	942	788	**633**
95	151	129	107	926	779	632
100	147	126	105	912	770	628

SECOND-GROWTH WHITE PINE AS AN INVESTMENT.

With the market and labor conditions now prevailing in New England and elsewhere within the range of white pine, second-growth stands, when properly managed, should yield a relatively high rate of interest. In this chapter the factors which bear upon the success of investments in second-growth white pine will be taken up separately, and their combined effect considered when returns at different rates of interest are desired. The values and costs used are based on a careful study of actual conditions in New England.

Two things determine the profit or loss from investments in second-growth white pine: (1) The gross returns from the financially mature stand, here regarded as the stumpage value, and (2) the total cost of raising white-pine stands at compound interest to the end of the rotation. Strictly speaking, the gross returns would be the price received for the lumber delivered, but, since stands are ordinarily valued in terms of the standing timber, stumpage value can be considered the gross returns. If the total cost of production equals the gross returns, the investment is a success. If the gross returns exceed the cost, the excess represents either a higher rate of interest than anticipated or a clear profit at the original interest rate. If the cost exceeds the stumpage value, the investment at the original rate of interest has been unsuccessful, although at a lower rate it *may* have yielded a profit.

GROSS RETURNS.

The value of standing timber is the difference between the market value of the finished product and the total cost of cutting, manufacture, and delivery, including the operator's profit on his investment.

Market Value of Lumber.

The chief product of second-growth pine stands, as already mentioned, is round-edged box board lumber and match stock. In most second-growth stands the lumber yield consists of two grades, both round-edged: One-inch box boards or siding, worth from $12 to $15 per thousand board feet, and 1⅝ to 2⅛ inch box boards and match lumber, worth from $17 to $18 per thousand. In addition, there may also be a small amount of sash and blind stock, worth from $30 to $35 per thousand. As the trees increase in size larger and consequently more valuable lumber can be had, and the proportion of 1-inch siding diminishes. Thus, lumber from logs 5 inches in diameter at the small end is made up of from 17 to 25 per cent of 1-inch siding, while in 10-inch logs the proportion is less than 8 per cent, and in logs over 18 inches at the small end it is negligible. The increase in value of the lumber from second-growth stands up to 70 years of age is shown in Table 8.[1] The values per thousand board feet are based on the values and the approximate proportion of the various grades just mentioned. From the values per thousand board feet and the board foot yields given in Table 6, values per acre were obtained. The figures given in Table 8 are the approximate values of the manufactured lumber delivered at the local market, and should not be mistaken for stumpage values, which are these values minus all costs of exploitation.

Table 8.—*Value f. o. b. local markets of lumber from second-growth pine stands of various ages and qualities.*

Age.	Value.					
	Quality I.		Quality II.		Quality III.	
	Per thousand board feet.	Per acre.	Per thousand board feet.	Per acre.	Per thousand board feet.	Per acre.
Years.						
20	$13.00	$58.50	.....	.....	.....	.....
25	14.50	121.80	$13.00	$70.20	.....	.....
30	16.20	225.18	14.50	139.20	$13.00	$68.90
35	17.30	389.25	16.20	257.58	14.50	134.85
40	17.80	583.84	17.30	406.55	16.20	230.04
45	18.00	752.40	17.80	544.68	17.30	332.16
50	18.20	893.62	18.00	658.80	17.80	428.98
55	18.30	1,006.50	18.20	764.40	18.00	522.00
60	18.40	1,107.68	18.30	858.27	18.20	611.52
65	18.50	1,204.35	18.40	949.44	18.30	697.23
70	18.60	1,300.14	18.50	1,037.85	18.40	778.32

[1] There is reason to believe that by an early pruning and subsequent thinnings these values can be greatly increased for rotations of from 50 to 70 years.

Logging Costs.

Most of the second-growth pine is sawed by portable mills of 10,000 or 15,000 board-feet capacity. These can be moved cheaply from place to place, and a stand of 100,000 board feet usually warrants a set-up. The different parts of the lumbering operation vary somewhat in cost, but in New England, with a 9-hour day, would average about as follows per thousand board feet:

Cutting	$1.25
Skidding	2.25
Sawing and piling at mill	3.25

Insurance at the rate of 1½ per cent per year, or at a less rate for portions of a year, and interest on the logging investment, add to the cost about 25 cents per thousand board feet, and raise the average total cost, exclusive of hauling, to about $7 per thousand. This figure is used in deriving the succeeding tables for stumpage values and profit and loss. The cost would tend to be greater for small and less for large timber. Usually the lumber is air-dried at the mill for from 3 to 6 months after being sawed. Cutting is ordinarily done in the winter, sawing in the early spring, and hauling in August, after the haying season, when teams are available.

On level roads in average condition a good team can haul from 1,500 to 2,200 (average 1,800) board feet of air-seasoned 2⅛-inch white-pine lumber to the wagonload. In many localities a distance from market of from 5 to 11 miles is considered a "one turn" haul. For shorter distances the tendency is to increase the loads and rest the horses oftener, while for long hauls the load might be reduced to 1,200 or 1,300 board feet. A single-horse wagonload usually contains from 700 to 900 board feet.

Hauling from the mill to the market is usually done under contract at either so much per day or at so much per thousand board feet. It is the most variable of the logging costs, since it depends upon the length of the haul, the character of the roads and topography, the wages paid for team and driver, and the amount of lumber that can be hauled at one load. It is, therefore, convenient to determine the cost of hauling in terms of the amount of lumber that can be hauled per day at a given wage rate. Five dollars per day is perhaps the most common rate for team and teamster throughout the northeast.[1] This rate is used in Table 9, which shows the cost of hauling and the total cost of logging for different amounts of lumber hauled per day by each team.

[1] The influence of different wage rates from $4 to $5.50 on the cost of logging and the stumpage value is discussed in Forest Service Bulletin 96, pages 20–29.

TABLE 9.—*Cost of hauling and total cost of logging per thousand board feet, for daily hauls per team of 1,000–4,000 board feet of lumber.*

Daily haul.	Hauling cost, with wage rate of $5 per day, per thousand board feet.	Total cost of logging, including hauling, per thousand board feet.
Board feet.		
1,000	$5.00	$12.00
2,000	2.50	9.50
3,000	1.67	8.67
4,000	1.25	8.25

The total cost per acre of logging average second-growth stands, based on the total cost per thousand in Table 9 and the yields given in Table 6, are shown in Table 10.

TABLE 10.—*Total cost per acre of logging and hauling, for stands of different ages and qualities, and for daily hauls, per team, of 1,000–4,000 board feet of lumber.*

[Based on yields given in Table 6, and costs per thousand board feet from Table 9.]

Age.	Daily haul, per team, 1,000 board feet.			Daily haul, per team, 2,000 board feet.			Daily haul, per team, 3,000 board feet.			Daily haul, per team, 4,000 board feet.		
	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.
Yrs.												
20	$54.00	.....	.....	$42.80	.....	.....	$39.00	.....	.....	$37.10	.....	.....
25	100.80	$64.80	.....	79.80	$51.30	.....	72.80	$46.80	.....	69.30	$44.50	.....
30	166.80	115.20	$63.60	132.00	91.20	$50.40	120.50	83.20	$46.00	114.70	79.20	$43.70
35	270.00	190.80	111.60	213.80	151.00	88.40	195.10	137.90	80.60	185.60	131.20	76.70
40	393.60	282.00	170.40	311.60	223.30	134.90	284.40	203.80	123.10	270.60	193.90	117.20
45	501.60	367.20	230.40	397.10	290.70	182.40	362.40	265.30	166.50	344.90	252.50	158.40
50	589.20	439.20	289.20	466.50	347.70	229.00	425.70	317.30	209.00	405.10	302.00	198.80
55	660.00	504.00	348.00	522.50	399.00	275.50	476.90	364.10	251.40	453.80	346.50	239.30
60	722.40	562.80	403.20	571.90	445.50	319.20	521.90	406.60	291.30	496.70	387.00	277.20
65	781.20	619.20	457.20	618.50	490.20	362.00	564.40	447.40	330.30	537.10	425.70	314.30
70	838.80	673.20	507.60	664.00	533.00	401.90	606.00	486.40	366.70	576.70	462.80	349.00

NOTE—The costs in Table 10 are based on an assumed average for all ages. As a matter of fact, since it costs more to log small than large timber, the logging cost (exclusive of hauling) would decrease slightly with the age of the stand.

OPERATOR'S PROFIT.

In computing stumpage value there should be deducted from the market value of the lumber not only the logging costs but also the amount of profit which an operator who bought the timber could be expected to demand on his investment. The profit represents the legitimate income upon the money invested, both in the standing timber itself and in the cutting, manufacture, and delivery at the local market of the lumber. The rate of this profit would be fixed largely by such considerations as the length of time the timber must

be held before being cut, the rate of interest, risk, depreciation of equipment, and proportion of the time it is in use, competition, etc. In general, a profit of 10 per cent over and above all logging costs is probably warranted in most regions where there is a fairly continuous employment for the sawmill equipment, and this rate of profit has been used in deriving the stumpage values in Table 11.[1]

A 10 per cent profit on an investment in stumpage and logging amounts to one-eleventh of the market value of the lumber.[2] For second-growth pine lumber at the market values given in Table 8, the profit can therefore be obtained by dividing each value by 11. The profit per acre will be based on the average yields per acre given in Table 6. At 15, 20, 25, and 30 per cent this is, respectively, three-twenty-thirds, one-sixth, one-fifth, and three-thirteenths of the market value.

Stumpage Value.

Stumpage values per thousand board feet and per acre (based on the board-foot yields in Table 6) are given in Table 11. These were obtained by deducting the logging costs per acre (Table 10) and a 10 per cent profit on the combined stumpage and logging investment from the market values per acre given in Table 8.[2] They apply, for each quality, to stands of average yield, provided the market values and logging costs are identical with those used in this bulletin. The yield of individual stands may differ somewhat from the averages given, while the values and costs will, in all likelihood, vary with the locality. Where these are radically different the stumpage value is best found by means of the formula.

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[1] The effect on stumpage values of a 20 per cent profit is discussed in Forest Service Bulletin 96, pp. 24–29.

[2] In computing the stumpage values the formula $S=\frac{M}{1.0P}-C$ was used, in which S=stumpage value, M=market value, C=logging costs, and P=rate of profit on the combined investment in stumpage and logging. For different rates of profit this reduces to the following forms:

For a profit of 10 per cent: $S=\frac{10}{11}M-C$

15 per cent: $S=\frac{20}{23}M-C$

20 per cent: $S=\frac{5}{6}M-C$

25 per cent: $S=\frac{4}{5}M-C$

30 per cent: $S=\frac{10}{13}M-C$

To determine the stumpage value obtainable, if any desired rate of profit is to be secured, the logging costs should therefore be deducted from the corresponding fraction of the market value.

TABLE 11.—*Stumpage values per thousand board feet and per acre of second-growth white-pine stands of average yield.*[1]

Age.	Quality.	Stumpage value, with hauling capacity, per team, of—							
		1 M per day.		2 M per day.		3 M per day.		4 M per day.	
		Per M.	Per acre.	Per M.	Per acre.	Per M.	Per acre.	Per M.	Per acre.
Years.									
20	I	.....	.....	$2.32	$10.50	$3.15	$14.00	$3.57	$16.00
	II	.....	.....	.....	.....	.....	.....	.....	.....
	III	.....	.....	.....	.....	.....	.....	.....	.....
25	I	$1.18	$10.00	3.68	31.00	4.51	38.00	4.93	41.50
	II	.....	.....	2.32	12.50	3.15	17.00	3.57	19.50
	III	.....	.....	.....	.....	.....	.....	.....	.....
30	I	2.73	38.00	5.23	72.50	6.06	84.00	6.48	90.00
	II	1.18	11.50	3.68	35.50	4.51	43.50	4.93	47.50
	III	.....	.....	2.32	12.50	3.15	16.50	3.57	19.00
35	I	3.73	84.00	6.23	140.00	7.06	159.00	7.48	168.00
	II	2.73	43.50	5.23	83.00	6.06	96.50	6.48	103.00
	III	1.18	11.00	3.68	34.00	4.51	42.00	4.93	46.00
40	I	4.18	137.00	6.68	219.00	7.51	246.50	7.93	260.00
	II	3.73	87.50	6.23	146.50	7.06	166.00	7.48	175.50
	III	2.73	38.50	5.23	74.00	6.06	86.00	6.48	92.00
45	I	4.36	182.50	6.86	287.00	7.69	321.50	8.11	339.00
	II	4.18	128.00	6.68	204.50	7.51	230.00	7.93	242.50
	III	3.73	71.50	6.23	119.50	7.06	135.50	7.48	143.50
50	I	4.55	223.00	7.05	346.00	7.88	386.50	8.30	407.50
	II	4.36	159.50	6.86	251.00	7.69	281.50	8.11	297.00
	III	4.18	101.00	6.68	161.00	7.51	181.00	7.93	191.00
55	I	4.64	255.00	7.14	392.50	7.97	438.00	8.39	461.00
	II	4.55	191.00	7.05	296.00	7.88	331.00	8.30	348.50
	III	4.36	126.50	6.86	199.00	7.69	223.00	8.11	235.50
60	I	4.73	284.50	7.23	435.00	8.06	485.00	8.48	510.50
	II	4.64	217.50	7.14	334.50	7.97	373.50	8.39	393.50
	III	4.55	152.50	7.05	236.50	7.88	264.50	8.30	278.50
65	I	4.82	313.50	7.32	476.50	8.15	530.50	8.57	558.00
	II	4.73	244.00	7.23	373.00	8.06	416.00	8.48	437.50
	III	4.64	176.50	7.14	272.00	7.97	303.50	8.39	319.50
70	I	4.91	347.00	7.41	521.50	8.24	579.50	8.66	609.00
	II	4.82	270.50	7.32	410.50	8.15	457.00	8.57	480.50
	III	4.73	200.00	7.23	305.50	8.06	341.00	8.48	358.50

[1] Based on yields, values, and costs given in preceding tables. The values per acre are rounded off to the nearest 50.

COST OF RAISING STANDS.

The costs in connection with raising white pine may be classed as initial and annual expenses. The former include the costs of formation (planting, sowing, and natural reproduction) at compound interest to the end of the rotation, together with interest on the initial value of the land. The latter include taxes on land and timber, and annual costs of protection and administration, both chargeable as annuities at a specific interest rate. Since the land remains an asset when the timber is cut, only the interest on it need be figured as an actual outlay.

VALUE OF THE LAND.

One of the chief arguments in favor of timber raising is that it presents a means of profitably utilizing waste lands. Wherever a greater income can be secured by some other use of the soil, timber growing can not be considered financially warranted. The ordinary situations in which it can be carried on with financial success include

areas which are nonagricultural because of broken topography and high altitude, or a poor, stony, or sandy soil. A distance from market of 10 or 15 miles, with good level or down-grade roads, is not prohibitive, provided the soil is good enough to produce quality I yields. The ideal situation is one close to a good market where the soil is deep, fertile, and well-drained, but too steep and broken to have a high value. Land suitable for raising white pine can ordinarily be obtained in New England for from $3 to $7 per acre. In computing the costs of raising white pine given in this bulletin a land value of $5 per acre is assumed as average. The interest on the initial value of $5 per acre, computed for different periods, is shown in Table 12.

Initial Cost of Formation

Often, as on abandoned pastures adjoining farm woodlots, the young stand becomes established without entailing any cost. More often, however, rapid growing hardwood sprouts or seedlings handicap the pine, and their removal involves some expense. Sometimes, too, it is necessary to sow or plant the whole or part of the area. The costs of these operations are discussed elsewhere in this bulletin. In considering their influence upon the whole investment it is sufficient to deal simply with the total expense of formation without regard to the way in which it was incurred. Table 12 shows by decades the amounts to which formation costs of $3, $6, $9, $12, and $15 accumulate when at 4 and 6 per cent interest. In Tables 14 to 17 results where no cost of formation is incurred are also given.

Table 12.—*Costs of raising white-pine stands (not including taxes) at compound interest, by decades.*

Interest rate.	Age.	Cost of formation, carried to end of rotation.					Interest on land value of $5 per acre.	Protection and administration at 5 cents per acre.
		$3.	$6.	$9.	$12.	$15.		
	Years.							
4 per cent.	20	$6.57	$13.14	$19.72	$26.29	$32.87	$5.96	$1.49
	30	9.73	19.46	29.19	38.92	48.65	11.22	2.81
	40	14.40	28.81	43.21	57.61	72.02	19.00	4.75
	50	21.32	42.64	63.96	85.28	106.60	30.53	7.64
	60	31.56	63.12	94.68	126.24	157.79	47.60	11.90
	70	46.79	93.43	140.14	186.86	233.57	72.86	18.21
6 per cent.	20	9.62	19.24	28.86	38.48	48.11	11.04	1.84
	30	17.23	34.46	51.69	68.92	86.15	23.72	3.95
	40	30.86	61.72	92.57	123.43	154.29	46.43	7.74
	50	55.26	110.52	165.78	221.04	276.30	87.10	14.52
	60	98.97	197.93	296.90	395.86	494.82	159.94	26.66
	70	177.23	354.46	531.70	708.92	886.16	290.39	48.40

Protection and Administration.

Protection and administration may involve a slight annual outlay, though in States which employ an efficient patrol during the fire season that for the former may be so small as to be scarcely a factor in timber raising. Administration provides for time spent in looking over the property. In Table 12 an annual administrative and protective cost of 5 cents per acre is compounded at 4 and 6 per cent interest for 10-year periods up to the age of 70 years.

Taxes.

Tax assessments on timberlands are commonly based on rough appraisals in which the land and the timber are not considered separately.[1] The tax rate varies considerably, but a common one in the pine regions of New England is $2 per $100 on a two-thirds valuation. In computing the accumulated tax per acre for this bulletin land and timber were assumed to be valued separately. Since the value of the land is a constant one of $5 per acre, the taxes are figured as an annuity. The increase in value of the growing timber is taxed on the basis of the stumpage values given in Table 11, which implies that the taxable value of the stumpage remains reasonably constant for a 5-year period. The taxes accumulated for each period are carried at compound interest to the end of the rotation, when the total accumulations from all the periods represent the total accrued stumpage tax at a specified age. These amounts are shown in Table 13. The tax rate used is $1\frac{1}{2}$ per cent on full valuation, corresponding to $2\frac{1}{4}$ per cent on a two-thirds valuation. This rate is slightly higher than the usual one, and together with the strict valuation imposed by Table 11 results in accumulated taxes probably in excess of the actual amounts. This was done to avoid the danger of underrating the total cost of growing the timber. With a lower tax rate the age at which the stand can be most profitably cut would be slightly extended and the profits increased.

The relation between stumpage value, taxes, and other producing costs, and their effect on the length of the rotation, is shown in Table 34, Appendix.

[1] Taxation of forest lands is discussed in a paper under this title by J. H. Foster (Biennial Report, 1907–8, Forestry Commission, State of New Hampshire, pp. 47–118), and also in a report of the Wisconsin State Board of Forestry in cooperation with the Forest Service, entitled "Taxation of Forest Lands in Wisconsin," by A. K. Chittenden and Harry Irion.

TABLE 13.—*Accumulated taxes on land and timber at rate of 1½ per cent on full valuation, at compound interest, by decades to the seventieth year.*

[Distance from stand to market permits a daily haul, per team, of 1,000 and 3,000 board feet of lumber.]

Interest rate.	Age.	Taxes on land.	Taxes on timber.[1]					
			Quality I.		Quality II.		Quality III.	
			Daily haul per team.		Daily haul per team.		Daily haul per team.	
			1,000 board feet.	3,000 board feet.	1,000 board feet.	3,000 board feet.	1,000 board feet.	3,000 board feet.
	Years.							
4 per cent.	30	$4.21	$0.81	$4.48	.....	$1.41	.....	.....
	40	7.13	11.79	27.82	$4.64	14.22	$0.92	$4.95
	50	11.45	45.89	91.68	25.91	56.14	10.98	27.00
	60	17.85	107.86	209.53	69.65	137.82	36.50	76.03
	70	27.32	213.26	401.23	144.42	274.69	83.46	163.35
6 per cent.	30	5.93	.85	4.79	.....	1.47	.....	.....
	40	11.61	12.92	31.50	4.94	15.70	.96	5.44
	50	21.78	54.12	111.48	29.56	66.35	12.13	30.91
	60	40.00	140.46	280.48	87.18	178.63	43.82	94.74
	70	72.60	310.29	602.07	201.35	397.43	110.68	225.27

[1] Assessments assumed to be made at 5-year intervals, on the basis of the stumpage values given in Table 11, and the taxes for each 5-year period (accumulated as an annuity) carried at compound interest to the end of the rotation. The figures given in the table are thus the sum of the accumulated taxes for the last 5-year period plus those for all preceding 5-year periods at compound interest to the specified year.

RETURNS TO BE EXPECTED.

The value of an investment in raising white pine may be determined by finding either (1) the precise rate of interest at which the stumpage value exactly equals the cost of growing, or (2) the amount of surplus profit when the stumpage value exceeds the cost of growing, computed at any desired rate of interest. The first of these methods is illustrated in Table 14, and the second in Tables 15, 16, and 17, which show the highest surplus profit or the least loss resulting when the costs are computed at 4, 5, and 6 per cent compound interest. From Table 14 it is apparent that the rate of interest is highest in quality I stands, close to market, which were started by natural seeding; and that it is lowest in planted stands in quality III situations, at some distance from market. This table also shows that investments which return a high rate of interest mature earlier than those yielding a lower rate.

These figures can be used safely in estimating the returns from investments in which the costs are no higher and the anticipated yields no lower than those given in preceding tables. It should be remembered, however, that they are based on the yields of fully stocked stands, and in using them it is well to allow for understocked and unmerchantable portions of the stand by assuming the area to be smaller but fully stocked. A deduction of from 10 to 20 per cent of the area, depending upon intensity of management, should be ample.

TABLE 14.—*Rate of interest on the total investment earned by second-growth stands under different conditions.*[1]

Amount hauled daily per team.	Cost of formation.	Quality I.		Quality II.		Quality III.	
		Most profitable rotation.	Interest rate.	Most profitable rotation.	Interest rate.	Most profitable rotation.	Interest rate.
Board ft.		*Years.*	*Per cent.*	*Years.*	*Per cent*	*Years.*	*Per cent.*
1,000	.....	40	7.7	40	6.6	50	5.3
	$3.00	40	6.7	45	5.7	50	4.5
	6.00	40	5.9	45	5.0	50	3.9
	9.00	40	5.3	45	4.5	50	3.5
	12.00	40	4.9	45	4.1	55	3.0
	15.00	40	4.5	45	3.8	55	2.7
2,000	.....	35	9.1	40	7.8	45	6.4
	3.00	35	7.8	40	6.8	45	5.5
	6.00	40	7.1	40	6.1	45	4.9
	9.00	40	6.5	40	5.6	50	4.4
	12.00	40	6.0	45	5.1	50	4.0
	15.00	40	5.6	45	4.8	50	3.7
3,000	.....	35	9.6	40	8.2	45	6.7
	3.00	35	8.2	40	7.2	45	5.8
	6.00	40	7.4	40	6.4	45	5.2
	9.00	40	6.8	40	5.8	45	4.7
	12.00	40	6.3	45	5.4	45	4.3
	15.00	40	5.9	45	5.0	50	4.0
4,000	.....	35	10.0	40	8.3	45	6.8
	3.00	35	8.3	40	7.3	45	5.9
	6.00	40	7.5	40	6.6	45	5.3
	9.00	40	6.9	40	6.0	45	4.9
	12.00	40	6.5	40	5.5	45	4.4
	15.00	40	6.1	45	5.1	50	4.1

[1] Based on the stumpage and cost data given in preceding tables. The interest rates were determined graphically by curving the profits and losses found by computing the initial and annual expenses at several fixed rates of interest. This method, devised by Mr. W. B. Barrows, is described in the Proceedings of the Society of American Foresters, vol. 8, No. 3, p. 362.

TABLE 15.—*Profit and loss per acre from raising white pine under different conditions, showing ages between which stand could be cut with profit, the most profitable age, and the maximum profit,* **as a 4 per cent investment.**

Daily hauling capacity for one team.	Cost of formation.	Quality I.			Quality II.			Quality III.		
		Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.
Bd. ft.		*Years.*	*Years.*		*Years.*	*Years.*		*Years.*	*Years.*	
1,000	.....	30–*	50	$127.67	35–*	55	$84.25	40–65	55	$42.86
	$3.00	30–65	50	106.35	35–65	50	62.86	45–60	50	18.86
	6.00	35–60	50	85.03	40–60	50	41.54	.....	50	− 2.46
	9.00	35–60	45	64.97	40–55	45	23.31	.....	45	−24.61
	12.00	35–55	45	47.44	45	45	5.78	.....	45	−42.14
	15.00	40–50	45	29.92	.....	45	−11.74	.....	45	−59.66
2,000	.....	20–*	50	216.11	30–*	50	153.01	35–*	55	95.98
	3.00	25–*	50	194.79	30–*	50	131.69	40–65	55	70.04
	6.00	25–65	50	173.47	35–65	50	110.37	40–60	50	45.91
	9.00	30–65	50	152.15	35–60	50	89.05	45–55	50	24.59
	12.00	30–60	50	130.83	35–60	50	67.73	50	50	3.27
	15.00	30–60	45	113.17	40–55	50	46.41	.....	45	−18.22
3,000	.....	20–*	50	245.38	25–*	55	177.45	35–*	55	113.41
	3.00	25–*	50	224.06	30–*	50	154.51	35–*	55	87.47
	6.00	25–65	50	202.74	30–65	50	133.19	40–65	55	61.77
	9.00	30–65	50	181.42	35–65	50	111.87	40–60	50	40.45
	12.00	30–60	50	160.10	35–60	50	90.55	45–55	50	19.13
	15.00	30–60	45	140.74	35–60	45	72.11	.....	50	− 2.19
4,000	.....	20–*	50	260.22	25–*	55	189.25	30–*	55	122.31
	3.00	25–*	50	238.90	30–*	50	166.10	35–*	55	96.37
	6.00	25–65	50	217.58	30–65	50	144.78	40–65	55	70.43
	9.00	25–65	50	196.26	35–65	50	123.46	40–60	50	48.55
	12.00	30–60	50	174.94	35–60	50	102.14	45–55	50	27.23
	15.00	30–60	45	154.74	35–60	45	82.70	45–50	50	5.91

NOTE.—The stars indicate an age of over 70 years. The computation was not extended to stands over 70 years old, although under certain conditions a rotation of more than 70 years could undoubtedly be employed with profit

TABLE 16.—*Profit and loss per acre from raising white pine under different conditions, showing ages between which stand could be cut with profit, the most profitable age, and the maximum profit,* **as a 5 per cent investment.**

Daily hauling capacity for one team.	Cost of formation.	Quality I.			Quality II			Quality III.		
		Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.
Bd. ft.		*Years.*	*Years.*		*Years.*	*Years.*		*Years.*	*Years.*	
1,000	.....	30–60	45	$96.88	35–60	45	$56.21	45–55	50	$10.75
	$3.00	35–55	45	69.92	40–50	45	29.25	.....	45	— 18.20
	6.00	35–50	45	42.97	45	45	2.30	.....	45	— 45.15
	9.00	40–45	45	16.01	.....	40	— 25.86	.....	40	— 70.87
	12.00	.....	40	— 4.95	.....	40	— 46.98	.....	35	— 89.08
	15.00	.....	40	— 26.07	.....	40	— 68.10	.....	35	—105.62
2,000	.....	25–60	50	179.32	30–65	50	120.08	40–60	50	58.14
	3.00	25–60	45	151.13	35–60	45	91.17	40–55	50	23.74
	6.00	30–55	45	124.18	35–55	45	64.22	.....	45	— 4.11
	9.00	30–55	45	97.22	40–50	45	37.26	.....	45	— 31.07
	12.00	35–50	45	70.27	40–45	45	10.31	.....	45	— 58.02
	15.00	35–50	45	43.31	.....	45	— 16.65	.....	40	— 80.77
3,000	.....	20–65	50	207.26	30–65	50	142.15	35–65	50	73.66
	3.00	25–60	45	178.03	30–60	45	111.68	40–55	50	39.26
	6.00	30–55	45	151.08	35–55	45	84.73	45–50	45	9.37
	9.00	30–55	45	124.12	35–50	45	57.77	.....	45	— 17.59
	12.00	30–50	45	97.17	40–50	45	30.82	.....	45	— 44.54
	15.00	35–50	45	70.21	40–45	45	3.86	.....	40	— 70.12
4,000	.....	20–65	50	221.36	25–65	50	153.36	35–65	50	81.59
	3.00	25–60	45	191.65	30–60	45	122.10	40–55	50	47.19
	6.00	25–60	45	164.70	35–55	45	95.15	45–50	45	16.24
	9.00	30–55	45	137.74	35–55	45	68.19	.....	45	— 10.72
	12.00	30–55	45	110.79	40–50	45	41.24	.....	45	— 37.67
	15.00	35–50	45	83.83	40–45	45	14.28	.....	40	— 64.71

TABLE 17.—*Profit and loss per acre from raising white pine under different conditions, showing ages between which stand could be cut with profit, the most profitable age, and the maximum profit,* **as a 6 per cent investment.**

Daily hauling capacity for one team.	Cost of formation.	Quality I.			Quality II.			Quality III.		
		Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.
Bd. ft.		*Years.*	*Years.*		*Years.*	*Years.*		*Years.*	*Years.*	
1,000	.....	30–50	45	$63.08	40–50	45	$23.53	.....	45	—$23.41
	3.00	35–45	40	27.60	.....	40	— 13.99	.....	35	— 59.43
	6.00	.....	40	— 3.26	.....	40	— 44.85	.....	35	— 82.49
	9.00	.....	40	— 34.11	.....	30	— 73.93	.....	35	—105.55
	12.00	.....	35	— 60.09	.....	30	— 91.17	.....	35	—128.61
	15.00	.....	25	— 77.82	.....	30	—108.40	.....	35	—151.66
2,000	.....	25–55	45	142.12	30–55	45	84.28	40–50	45	17.20
	3.00	30–50	45	100.83	35–50	45	42.99	.....	45	— 24.09
	6.00	30–50	40	64.90	40–45	40	5.86	.....	30	— 55.77
	9.00	35–45	40	34.05	.....	40	— 24.99	.....	30	— 72.99
	12.00	40	40	3.19	.....	40	— 55.85	.....	30	— 90.23
	15.00	.....	40	— 27.67	.....	35	— 83.97	.....	30	—107.46
3,000	.....	25–55	45	168.17	30–55	45	104.35	40–50	45	30.53
	3.00	25–55	45	126.88	35–50	45	63.11	.....	45	— 10.76
	6.00	30–50	40	87.38	40–45	45	21.81	.....	40	— 46.92
	9.00	35–45	40	56.53	.....	40	— 8.21	.....	30	— 68.59
	12.00	35–45	40	25.67	.....	40	— 39.07	.....	30	— 85.83
	15.00	.....	40	— 5.19	.....	40	— 69.93	.....	30	—103.06
4,000	.....	20–55	45	181.37	30–55	45	114.62	40–55	45	37.31
	3.00	25–55	45	140.08	35–50	45	73.33	.....	45	— 3.98
	6.00	30–50	45	98.78	35–50	45	32.03	.....	40	— 41.52
	9.00	35–50	40	67.91	40	40	.33	.....	30	— 66.37
	12.00	35–45	40	37.05	.....	40	— 30.53	.....	30	— 83.61
	15.00	40	40	6.19	.....	40	— 61.39	.....	30	—100.84

MANAGEMENT.

In the preceding chapter it was shown that white pine raising can usually be counted on to bring returns of 4, and often of 6, per cent or more. It thus offers a means of deriving a substantial net income from land which would otherwise be almost or wholly useless. Trees demand but little time and labor as compared with other crops, for while some care must be given to make sure that the young stand gets the proper start, its later development may be left largely to nature, with but little expense besides taxation and protection—common charges on any property.

While nature can be relied upon to produce the lumber yields and incomes given in Tables 6, 14, 15, 16, and 17, the yield, and consequently the value of white-pine stands, can be materially increased by artificial means, such as thinnings, improvement cuttings, and efficient methods of reproduction, all commonly combined under the term "management." Of course, no detailed plan of management can be given which will apply alike to all white-pine stands. Knowing the characteristics of the tree as outlined in the first part of this bulletin, however, it is possible to formulate broad methods of management for pure and mixed stands of white pine. Local conditions, especially in mixed stands, will necessarily call for modifications in the general plan, but these will not be wide departures, and in all likelihood will suggest themselves as the management of the stand proceeds.

SECOND GROWTH.

Stands are said to be even aged if the trees composing them vary in age by less than 20 years. They are called pure if they contain 80 per cent or more of a single species, and mixed if they contain two or more species no one of which forms 80 per cent of the stand. Pure, even-aged stands of second growth seldom develop on land not previously cultivated or burned over, even where the original stand consisted chiefly of pine. This has led to the erroneous belief that pine would never follow pine. The failure of pine to succeed itself is due to the slow growth and intolerance of shade of the young seedlings, which are overtopped by the various broadleaf trees which spring up on clearings. The resulting stand may be exclusively of hardwoods or contain a limited proportion of pine. Even on land previously cultivated, mixed stands will appear when the area receives seed from both pine and hardwoods.

Pure, Even-aged Stands.

Pure, even-aged stands of white pine yield more lumber per acre, age for age, than pure stands of any other species in the Northeast. This is due partly to their rapid growth and partly to the low grades

of lumber which can be marketed. Pine branches are so persistent that lumber of higher grades than box boards, match stock, and a very little sash and blind stock can hardly be produced in short rotations except by means of systematic pruning (see p. 38).

ROTATION.

Under "White pine as an investment" it was shown that the age at which the pine should be cut in order to secure the greatest profit varied with the rate of interest used. The lower the interest, the greater will be the age, called the age of financial maturity. If, for example, the investor demands only 4 per cent, the stand can, under most conditions, be profitably left until it is 50 years old. If 6 per cent is desired, however, rotation should not be over 40 or 45 years. Unfortunately the financial maturity of a stand at the interest rates given rarely coincides with its volume maturity in board feet. From the standpoint of volume the pine has matured at the age when its average annual growth per acre is greatest. The age at which volume matures is shown for different qualities in Table 7. In quality I situations the volume maturity in board feet occurs, as a rule, when the stand is from 55 to 65 years old; in quality II, between 70 and 80 years; and in quality III, between 85 and 95 years. In the future, when timber is much scarcer than it is now, the volume maturity may often coincide with or precede the financial maturity. At the present, however, it is the latter which should be the guide in management.

Since the stand should be removed only during heavy seed years, which occur at intervals of from 3 to 7 years, it can rarely be cut in precisely the year when it is financially mature. A good rule to follow if the stand is to be cut clear is to remove it during the seed year next following maturity. If two or more cuttings are planned, the first may be made during a year of prolific seed production preceding maturity by from 3 to 7 years, and the later cuttings in subsequent seed years.

THINNINGS.

In dense stands of pine there is an intense competition between individuals for light and growing space. As a dominant tree falls behind its more vigorous neighbors it becomes in turn codominant, intermediate, and overtopped, and finally dies for lack of light. The struggle is thus most critical in the dominant class. The other classes are on the road to elimination, though until finally suppressed they continue to crowd the dominant trees and retard their volume growth.

Thinnings aim to increase the volume growth of dominant trees by removing from time to time trees of other classes which are unduly crowding them (see Pl. V). In this way the total growth of the stand is concentrated in the smallest number of thrifty trees

FIG. 1.—A 50-YEAR-OLD WHITE PINE STAND BEFORE THINNING. SOUTHERN NEW HAMPSHIRE.

FIG. 2.—SAME STAND PROPERLY THINNED.

WHITE PINE PLANTATION, 22 YEARS OLD THINNED AT AGE OF 15 YEARS.

which will occupy the area. If these are pruned of branches to a height of 16 or 17 feet, the value of the future increment will be materially increased. At the same time the trees removed, which would otherwise be wasted, may yield a moderate return. As a result of successive thinnings at intervals of from 5 to 10 years, the aggregate yield, including the material saved in the thinnings, will be increased, while the trees finally harvested will be larger, sounder, and better formed than in unmanaged stands.

The best time to thin a stand is during the period of its most rapid height growth, though this occurs so early in its life that enough merchantable material to pay for the thinning can rarely be obtained. An early unremunerative thinning may, however, more than pay for itself by increasing the value both of the final stand and of the material removed in later thinnings (see Pl. VI).

In all thinnings any undesirable hardwoods which may be present should be removed. Thinnings should leave the stand uniformly opened up to an extent which insures that crowns of the trees left will not come together again for four or five years. More space should be left between the crowns when the trees are young and growth rapid than later. An average distance between the crowns of from 3 to 5 feet is probably sufficient in most cases, though the removal of undesirable hardwoods or of unsound or poorly formed pines may make somewhat larger openings unavoidable. Large openings in the crown cover, however, will result in poorly formed limby trees and should be avoided.

In quality I stands which have always been dense, a thinning may often be made with advantage as early as the fifteenth year. In stands which have been understocked in youth thinnings are, of course, unnecessary until considerably later, if warranted at all. Early thinnings, of course, represent a direct outlay, since little of the material removed will be fit even for cordwood. In farm woodlots such thinnings can often be made during leisure time without a real loss. The trees removed will be mainly codominant and intermediate. Dead and badly suppressed trees need not be cut, since they no longer interfere with the growth of the stand. Subsequent thinnings may be made at about the twentieth, twenty-fifth, and thirty-fifth year. Except that the last should be slightly heavier to allow the trees full space for volume growth up to the time of final cutting, the subsequent thinnings may be made in the same manner as the first. When the stand is 20 years old the material removed in thinning may be large enough for cordwood, and the operation pay for itself. Later thinnings should yield a profit. When necessary, the intervals between thinnings may be lengthened and the thinnings themselves made more severe. It is better, however, to thin lightly and often than heavily and at longer intervals.

In quality II situations, where the growth is slower, thinnings should be made lightly and often, in order not to expose the soil too much. Because of the relatively low returns to be expected from quality III stands, unremunerative thinnings in them may not be advisable. When enough fuel wood can be cut to make thinnings pay, however, one or two may be made with advantage.

The amount of wood removed in thinnings, irrespective of the age of the stand, is usually from 15 to 40 per cent (average about 26 per cent) of the total volume. It is less in previously thinned than in unthinned stands. The number of trees removed varies widely with the age of the stand and its past density. Ordinarily it ranges between 20 and 60 per cent, with an average of about 45 per cent.

PRUNING.[1]

Pruning has usually been condemned as expensive and likely to produce pitch pockets and loose knots, and at present is not widely practiced. While certain defects often result from pruning, these are in most cases due to wrong methods, and should not be considered evidence against pruning in general. There is reason to believe that if properly done the money expended in pruning will yield substantial returns.

Pruning should remove all dead branches, and usually a whorl or two of the lower live branches, flush with the trunk. Care should be taken not to injure the trunk; the saw is perhaps the safest and best instrument. By mounting it on a light 12-foot pole, the branches can be pruned to a height of 17 feet, thus providing for a clear lumber increment over one 16-foot log. The cost will be from 5 to 10 cents per tree. Pruning can be done at any season, but for live branches late fall or early winter is probably best, since the tree will suffer less from bleeding than at other seasons.

To be worth while, pruning must be done early in the life of the stand, preferably at an age of from 20 to 30 years, while the branches are still small and there is but a small amount of low-grade lumber at the heart. A safe rule is to prune to a height not over half that of the tree. A clear length of 17 feet would thus indicate a total height for the tree of 34 feet, but it is better to begin pruning when the tree is smaller, increasing the clear length by a subsequent pruning. In this way the maximum time is given for the accumulation of clear lumber during the remaining 30 years or more of the financial rotation.

Only those trees which are to be left until the final cutting should be pruned. For stands which are to be consistently thinned, the

[1] This subject is discussed in detail in "Silviculture of White Pine," by F. B. Knapp (Bulletin 106, Mass. Forestry Association, 4 Joy St., Boston). An example of the application of pruning to second-growth white pine is the stand belonging to and managed by Mr. O. M. Pratt, Holderness, N. H.

number of trees per acre at the end of a 50 or 60 year rotation, and therefore the number to be pruned, will probably be less than 200. Thrifty trees, scattered evenly through the stand, should be selected for pruning, and these should be favored in subsequent thinnings. In fact, pruning is practically useless if unaccompanied by thinning. Plantations in which pruning is to be practiced may be spaced wider than otherwise, and the saving in plant material and labor may often exceed the cost of pruning, which, in addition, will bear interest for a less number of years.

FINAL CUTTING AND NATURAL REPRODUCTION.

The mature crop should be harvested in such a way that the ground will be left evenly stocked with thrifty reproduction. Since pine seedlings soon demand full light, the removal of the mature stand should be complete, though not necessarily in a single year. There are four ways of providing the necessary seed supply for the cut-over area: (1) Clear cutting the entire stand during the fall and winter of a prolific seed year; (2) clear cutting in strips from 100 to 150 feet wide to be seeded from the side; (3) clear cutting with scattered seed trees; (4) the shelter-wood method of successive partial cuttings over the whole area.

Clear cutting the whole stand.—Clear cutting the whole stand in one operation is the cheapest method, since it is not necessary to return later for a second cut. It is especially suitable for small areas of 4 or 5 acres with adjacent bodies of seed-bearing pine. If done after a heavy fall of seed, young pines will usually appear in abundance the subsequent spring. Care must be taken for the first 5 or 6 years to see that valueless rapid-growing hardwood seedlings and sprouts, which are usually present, do not choke out the pine (see Pl. III, fig. 2). When young pine seedlings are thus threatened, the slender hardwood saplings should be lopped back at a height of from 1 to 2 feet from the ground with a sharp corn knife or brush hook. This is known as a "disengagement cutting." It should be done when the young stand is 6 or 8 years old, when the pines will usually be from 2 to 6 feet and the hardwoods from 6 to 12 feet high. If released at this age the young pines should have little trouble in keeping down the hardwoods thus handicapped.

The cost of lopping will vary with the size of the saplings and the efficiency and cost of labor. In a fairly dense stand a good man can cover from 1 to 2 acres per day, provided the hardwoods are small enough to be severed with a single stroke of the knife. Lopping should be done during the summer, if possible, since the hardwoods are apt to sprout less vigorously then than after a cutting in winter or early spring. Often a second cutting four or five years later will be necessary. This will consist chiefly in cutting back the more

aggressive sprouts which have succeeded in overtaking the young pines. Really valuable hardwoods, such as white ash or black cherry, need not, of course, be cut back with the others.

A judicious burning of the cleared area would destroy much of the competing vegetation, expose the mineral soil, and destroy the slash left after logging. On the other hand, it would also destroy most of the pine seed. It is not safe, therefore, to use fire except when adjacent timber insures an abundant seed supply or when artificial reproduction is contemplated. Furthermore, it involves some additional expense and inevitably results in more or less serious damage to the soil. Lopping of branches from the treetops after logging will cause the slash to lie flat on the ground, and so present the least risk of being ignited. At the same time it will give the young seedlings the shade they need, and by its decay add to the moisture retaining humus layer essential for the best growth of the stand. In situations exposed to intense sunlight or to drying winds the protection given by the lopped branches is especially beneficial. On clear-cut pine lots in New England excellent reproduction springs up in old slash, while open places often bear little or no young growth. Along railroad rights of way and in other places where the fire risk is great, the brush should, of course, be piled or scattered and burned. In such cases, however, it may be necessary to reproduce the stand by artificial means.

Clear cutting in strips.—Under this system the stand is cut in strips from 100 to 150 feet wide, while strips of equal width are left to seed up those cut over. When this is accomplished, the remainder of the timber is removed. Manifestly, enough timber must be left to warrant the expense of a second logging, and the total area or total yield of the stand must, therefore, be twice as large as when one cutting is made. With average yields a minimum area of 10 or 12 acres might warrant logging by this method, provided about half of the timber is removed in each of the two cuttings. On level land the strips should lie parallel and in a direction which will insure that the prevailing winds will blow the seed across the cleared areas. In rough country this arrangement will often have to be modified in order to facilitate logging. If it becomes necessary to cut the strips parallel to the prevailing wind, they should be narrower than otherwise, to insure a complete seeding. In making the second cut, if there are no adjacent seed-bearing trees to windward, reproduction must be secured by the seed tree or the shelterwood method, or artificially.

Where the area comprises 20 acres or more, with fairly uniform conditions, the strip method may be extended to allow 3, 4, or 5 cuttings at fairly regular intervals during the rotation. Thus, if the contemplated rotation was 60 years, one-third of the stand could be removed every 20 years, or one-fourth every 15 years, or one-fifth

every 12 years. The strips should run as nearly as possible at right angles to the prevailing winds. While, as with two cuttings, a width for the strips of 100 to 150 feet is best, the width of the intervening strips of standing timber must be sufficient to insure that the 3, 4, or 5 cuts will entirely remove the stand. If, for example, the average acre yield at 60 years of a 16-acre tract of pure white pine is 30,000 board feet, and the installation of a portable mill is warranted by a cut of 100,000 board feet, or $3\frac{1}{3}$ acres, 5 such cuttings at 12-year intervals would be possible with a rotation of 60 years. The side of the stand most nearly parallel to the prevailing wind should be divided into 5 parts, and each of these into approximately equal subdivisions from 50 to 100 feet wide. Each of the cuttings will then follow every fifth strip at right angles to the prevailing wind. Very few stands, however, are uniform throughout, and the width of the strips will have to depend somewhat upon local variation in the yield.

Any system of sustained yield through regular cuttings presupposes the existence of a reasonably steady market for the grades of lumber supplied. White pine lumber of medium and low grades promises to remain as steadily in demand as that of any other species in the Northeast. Even white pine lumber, however, will fluctuate in value, and the temptation will often be strong to overcut when the market is high, and lightly or not at all when the demand is poor. While modification in the original plan can be made only at a sacrifice in regularity in ensuing yields, it can not always be avoided, and constitutes a defect in the strip system. Absolute regularity, however, is often undesirable, even from a silvicultural standpoint, since a year's delay or hastening of the cut to take advantage of a seed year may greatly facilitate reproduction.

One great advantage of the strip method over clear-cutting the whole stand is the greater certainty of reproduction it offers. Should the young reproduction be destroyed by fire, the standing timber to windward can be depended upon to reseed the area. In fact, a light fire just before a heavy fall of seed, provided it is not allowed to spread into adjacent timber, may prove of great value by exposing the mineral soil and killing existing vegetation. As when only two cuttings are made, the last strips to windward may be reproduced by leaving seed trees or by planting or sowing. Disengagement cuttings will often be necessary to remove competition from fast-growing hardwood sprouts and underbrush.

Clear cutting with scattered seed trees.—In this method natural reproduction is secured by leaving three or four mature seed-bearing trees to the acre (see Pl. IV, fig. 2). These should be distributed as evenly as possible, but located with reference to the prevailing winds in a way to insure the most effective distribution of seed. Seed trees

should be windfirm. Those with large crowns and relatively thick trunks are least likely to be thrown. If, however, there is any question of windfirmness, it is usually best to leave the seed trees in groups of three or four for mutual protection.

When a thrifty reproduction has been secured, seed trees should be removed if it is profitable to do so. If they are well formed and sound, however, they may be left until the land is again cut over. In this way the cost of their removal will be lessened and lumber of larger size and possibly of better quality secured.

If seed trees are to be left, the stand may be logged before seed fall in a year of heavy production. This permits the logged area to be burned over lightly, should it be thought necessary to get rid of bushes and hardwood sprouts and seedlings. As in the other methods, disengagement cuttings should be made if the pine seedlings are threatened by hardwoods.

The seed-tree method has the advantage over the other methods described in that the area which can be cut over at any one time is unlimited. Since only one cutting is made in a rotation, there is no periodic income as in the strip method; but, on the other hand, the expense and trouble of logging come only once.

Shelterwood method.—The shelterwood or "stand" method removes the trees by successive thinnings or partial clearings at intervals of a few years. The object is to gradually establish thrifty reproduction under the best possible conditions and to preserve a seed supply in case of disaster to the young stand. In Germany, where the system originated, and where economic conditions allow of its intensive application, a large number of successive thinnings are made, classed as "preparatory," "seed," and "final" cuttings. The preparatory cuttings aim to increase the air circulation in dense stands, and thus facilitate decay of the humus and exposure of the mineral soil. They also stimulate seed production by admitting light to the tree crowns. From 25 to 40 per cent of the least desirable trees are removed, which reduces the density of the crown cover about one-fourth and leaves the dominant trees with their crowns separated by a space of from 3 to 5 feet. A few years later, when the soil is in good condition and seed production assured, the seed cutting is made. This is done during a seed year, and reduces the crown cover to at least one-half its original density, in order that sufficient light may be admitted for the expected reproduction. When the latter is so large, thrifty, and uniformly distributed as to leave no doubt of its success, the shelter trees are removed. If the seedlings show need of increased light before the final cutting, as they may within 3 or 4 years after the seed cutting, some of the remaining trees must be removed in advance. The whole thinning process takes from 15 to 20 years. At its conclusion, should it prove successful, a thrifty stand of young trees, all of

which are making rapid height growth, occupies the ground. The chief disadvantages of this method are the expense involved in logging, the damage to young growth caused by the removal of the larger trees, and the fact that, with the amount of light necessary for the pine seedlings, many tolerant hardwoods are likely to spring up and suppress the former. For white pine, therefore, this method should be modified so that only two cuttings, the seed and the final, are made. The first is made during an abundant seed year, and consists of a very heavy thinning which reduces the crown density fully one-half, entailing the removal of more than one-half the trees. Logging operations should disturb the leaf litter and expose the mineral soil for the germination of the pine seed. The trees left should be such of the dominant ones as give best assurance of windfirmness and seed-producing capacity. Good reproduction can be expected under these conditions. To insure the uniform stocking of the area, however, shelter trees are left standing until after at least the next seed year. All of them are then removed, when the mineral soil is again exposed and a chance given for new reproduction to take the place of that destroyed in logging. If logging is done in winter, however, when many of the seedlings are covered with snow, few of them will be damaged.

The slash left after each cutting should be lopped and scattered on the ground, or piled in the larger openings and burned. A disengagement cutting will probably be necessary a few years after the removal of the older trees.

This method has the advantage over that of leaving seed trees in that the entire stand is utilized, no trees being sacrificed to secure reproduction. It preserves a moist seed bed and insures the seedlings protection against too much light during their first year and against frost and drying winds up to the time when they are able to withstand them. By fostering a rank growth of weeds, underbrush, and hardwood seedlings, however, it offers an element of danger to the young pine (see Pl. V, fig. 1). Logging is more expensive than in clear cutting, with or without seed trees, because the ground is gone over twice and scattered trees must be taken in each operation.

Mixed Stands.

COMPOSITION AND IMPROVEMENT.

White pine grows in such a variety of mixtures, both with hardwoods and with other conifers, that it is impossible to outline definite rules for management that will fit all cases. In general, however, mixtures may be classed as desirable and undesirable. A desirable mixture is one in which the pine is well distributed among and overtops other valuable or more tolerant species. It was in such mixtures that the white pine of the original forests reached its best development. On suitable soils valuable hardwoods may be en-

couraged, provided the pines have received a sufficient start to keep their crowns above those of their associates. The diameter growth of pine in suitable mixtures, unlike that in pure stands managed on short rotations and unpruned, is accompanied by a marked improvement in the quality of the lumber, due to its greater freedom from knots. This comes about through the natural pruning of the pine branches by the relatively low and supple hardwood crowns. Another advantage of mixed stands consists in the relative freedom of the pine tops from damage by weevils, due to the isolated position of the pine among broadleaf trees inhabited by insect-eating birds.

Among the trees desirable for cultivation with white pine are beech, sugar, and red maple, yellow birch, basswood, red oak, white ash, and black cherry. These are arranged approximately according to ability to endure shade, beech being the most tolerant, cherry the least. Though their present economic value is relatively low, the tolerant species except red maple are also the slowest growing, which enhances their value as an understory for white pine. Cherry, ash, and red oak, on the other hand, produce lumber fully as valuable as that of white pine, but their rate of growth is only a little slower than that of the latter. Each class of associates, therefore, has a characteristic value in mixture with pine. As compared with pure stands managed on short rotations, the yield of the latter in a mixed stand may be considerably reduced, but where a higher quality of pine lumber is desirable and a market exists for the hardwoods, mixed stands operated on somewhat longer rotations are worthy of consideration.

Among the inferior associates of white pine are gray birch, large and small toothed aspen (popple), fire cherry, pitch pine, and jack pine. Most of these are undesirable simply because they monopolize ground upon which better species might be growing. Gray birch, however, is an active menace to any young pine in its vicinity, since its sprouts, swaying in the wind, soon kill the tender upper shoots of young pines growing near them.

TREATMENT.

The success of pine among hardwoods depends, for one thing, upon its overtopping the other species. This can usually be brought about by one or more disengagement cuttings made at about the time the pine is entering upon the period of its most rapid height growth. To secure mixed stands, of course, disengagement cuttings need not be as thorough as for pure pine stands, since the pines will be scattered, and only the hardwood saplings near them need be cut. It will be well, however, to remove inferior trees like gray birch, aspen, and fire cherry wherever they appear to threaten the existence of better species, such as white ash, red oak, and black cherry. Subsequent

weedings made at intervals of a few years will gradually remove from the stand all undesirable species. Stands should be kept fairly dense, however, and no trees need be removed which appear to be succumbing to the competition of more desirable associates. The expense of improving the composition and increasing the value of mixed stands should be relatively small.

The growth of valuable broadleaf seedlings which, like white ash, sprout vigorously from the stump may be accelerated by cutting them back when the last of the original stand is finally removed. The "seedling sprouts" thus produced grow very rapidly, and soon attain a commanding position in the stand. Ash and black cherry cast only a light shade, and the presence with the pine of a reasonable number of those trees will greatly increase the value of the stand, both through their value for lumber and through their tendency to clear the pine trunks of branches.

OLD GROWTH.

Only scattered remnants of the original white-pine forests remain. These, however, are being logged in such a way that the complete disappearance of pine from such areas is threatened. Attempts to secure natural reproduction have rarely been successful, either because of defects in management, or fire.

While fire more than any other agency may play havoc with the forest, yet, if rightly used in connection with lumbering, it may be the means of insuring a natural growth of white pine on cut-over areas. The soil on which white pine does best is good enough to support many kinds of woody undergrowth, as well as relatively worthless broadleaf trees. As long as the shade from the old pines is dense the undergrowth is kept down. When the pine reaches an advanced age, however, the crown cover becomes thinner and the woody and herbaceous undergrowth increases in abundance. When the stand is finally cut nothing remains to hinder the development of the brush and hardwoods. Should a fire burn over the area just before a heavy seed year, however, and should the cutting follow immediately after seed fall, an abundant stand of pine reproduction is almost sure to come in, giving competing vegetation little room in which to grow. The problem from then on consists simply of protecting the young growth from fire.

Since it is almost impossible to prevent occasional fires from burning over large areas of pine slashings and destroying the young reproduction upon them, it is necessary to provide some means of reseeding such areas. This can be done either by leaving scattered seed trees or, better still, by removing the stand by the shelterwood method. In either case cuttings should be made only during years of heavy seed production. In most cases a careful

burning over of the surface prior to the seed fall is necessary. The areas dealt with are ordinarily so large that disengagement cuttings are out of the question.

The seed-tree method has been employed in the white and Norway pine stands on the Minnesota National Forest (see Plate VII). Owing to the inadequacy of the law under which cuttings were made, however, it has not proved satisfactory except under accidental combinations of circumstances, such as the occurrence of severe ground fires before and not after a seed fall. The law provides that 10 per cent (originally 5 per cent), by volume, of the trees above 10 inches diameter breast high shall be left as seed trees. Since no adequate provision was made for the distribution of these, spaces left without seed trees were often too large, and very little reproduction resulted. The stand was cut not only during seed years, but also in years when there was absolutely no seed production. In the absence of cultural fires to free the ground from competing growth before the seed fall, the benefits of cutting during seed years are minimized, since most of the reproduction, even if abundant, is killed by the dense brush that rapidly springs up. On some areas which had been burned over during the spring or summer of a seed year and logged the following fall and winter, reproduction was excellent. On many of these, however, the young pine was killed by subsequent fires, and before the next seed year the ground was again covered with brush.

In lumbering old stands by the shelterwood method the first cutting should be made during a seed year and should be heavy enough to provide sufficient light for the pine seedlings without unduly encouraging the growth of brush. If reproduction is satisfactory—that is, if it should average at least 2,000 well-distributed seedlings per acre—a second cutting should be made during the first heavy seed year after the young pines are 5 or 6 years old. The stand may be cut clear at this time if the fire risk is small and the expense of leaving seed trees prohibitive. If, however, too much brush has sprung up since the first cutting, the ground should be thoroughly burned over in the spring or summer of the seed year in which the second cutting is made and seed trees or even enough of the stand to warrant a later cutting left on the ground.

Should the shelterwood method be thought too expensive, the seed-tree method may be used with good results if the cutting—made during a full seed year—is preceded by a thorough surface burning. The seed trees should be selected in advance from the most windfirm of the pines, and should be protected from surface fires by trenching or some other means. They should be well distributed at least 2 or 3 to the acre. Before each subsequent seed year, areas on which reproduction is poor should be carefully burned over.

WHITE PINE FOR WINDBREAKS AND RESERVOIR PROTECTION.

White pine is an excellent tree for windbreaks and shelter belts, and is planted largely for this purpose in the plains States. Its treatment as a shelter-belt tree is discussed in Forest Service Bulletin 86, "Windbreaks," by C. G. Bates. It is therefore unnecessary to consider it here.

For reservoir and watershed protection white pine has already been extensively planted throughout New England. Like other conifers, it is better than hardwoods for the purpose because its leaves do not readily blow into the reservoirs. Its rapid and hardy growth make it generally preferable to most other conifers wherever conditions are favorable for its growth.

Besides protection, the stand may be useful in producing timber. Where the double purpose is sought the pine should be grown in pure, even-aged stands. The rotation may, however, be much longer than that used when timber alone is desired. The shelterwood method, followed by ample disengagement cuttings and the planting of stock on bare areas, can be used to advantage.

PLANTING AND SOWING WHITE PINE.[1]

Throughout most of its range white pine is probably the most popular native tree for forest planting. In New England it has been set out chiefly for scenic effect and for reservoir protection, although there are a number of plantations for the commercial production of timber. Since one of the chief things to be considered in raising white pine is the cost of establishing the stand, it is necessary to compare the efficiency of different methods and to determine the cost involved in each.

White pine stands may be established artificially either by planting seedlings or by sowing seed directly on the area. Under most conditions planting offers the best chance for success, and is, in the long run, the cheaper method. Occasionally, however, favorable climatic and soil conditions insure the growth of excellent stands from artificially sown seed. Seeding is especially worthy of consideration where large areas have to be planted up in a limited time, but the method should never be used without first experimenting on small areas to determine its probable success.

There are a number of methods of planting and sowing which have proved successful under different conditions of site and labor. Whether an area is to be planted or sowed, the first step is to procure the seed.

[1] For a full discussion of methods and costs of artificial forestation see Forest Service Bulletin 76, "How to Grow and Plant Conifers in the Northeastern States," and Bulletin 98, "Reforestation on the National Forests."

OBTAINING THE SEED.

Seed may be procured either by purchase from dealers or by collecting the cones in the woods. If seeds are purchased, the dealer should be required first to furnish a sample and to guarantee that the remainder of the seed will be equal to it in quality. The sample should be tested by cutting open 100 or 200 with a sharp knife and observing the percentage of those which are plump, well-filled, and oily—indications of good quality. While the actual germination per cent will be lower than that shown by the cutting test, the result will be a reasonably safe guide to the quality of the seed. Seed is likely to be better and cheaper during years of abundant production than during off years. Wherever possible the climate of the region where the seed is collected should be like that in the region where it is used.

White-pine seed ordinarily costs from $1.40 to $4 per pound, averaging about $2.25. The cost of collecting seed, however, is relatively low, ranging from 60 cents to $2.50 per pound, and, if properly done, better seed can be secured than by purchase. Where the area to be planted or sown is large and cones can be obtained in quantities from a near-by forest, it may be advisable to collect the seed.

The cones should be collected just before they open, which is usually during the first half of September, or perhaps a week earlier or later, depending upon the season and the situation. In the open and on south exposures cones mature earlier than in dense woods or on north slopes. When some of the cones begin to turn brown it is usually time to collect them. Cones may be secured from trees felled in logging or, if lumbering is not going on, by climbing the trees and picking them off. Trees growing in the open bear more cones and are easier to climb than those in dense stands. Cones may sometimes be obtained from squirrels' hoards.

As soon as collected, or even while collection is in progress, the cones should be dried and the seeds extracted. Since rain or damp weather will handicap this work, it is best done indoors. If the weather is clear, however, the cones may be dried by spreading them out thinly on canvas sheets in the sun and wind. The sheets should be made into bundles at night or a loose flap thrown over the cones. If the weather becomes damp, drying should be completed indoors.

When the cones are dried indoors a room should be selected in which there is a free circulation of air, but which rodents and birds can not enter. The cones should be placed in racks made of laths laid parallel one-half inch apart, fastened at each end by laths nailed above and below. The racks, built like shelves one above the other about 18 inches apart on notched uprights fastened to the floor and ceiling, should be 4 feet square, which would give them a capacity of 2½ bushels of cones, though drying will be facilitated if a less amount

is used. The cones should be stirred frequently, and those which appear shrunken or wilted removed. Progress in drying will be indicated by the opening of the cones, announced by an audible pop or snap. When preliminary drying is completed the cones should be taken to a second room to be fully opened by artificial heat. This room, which must be reasonably air-tight, should contain a stove in one corner, with two pipes extending from a double elbow across the room and level with the top of the stove. Above the pipes should be tiers of wooden trays with bottoms of wire mosquito netting arranged one above the other, so that the heat will rise through them. A temperature of about 100° F. may be maintained in the room without injury to the seed. Before being placed in the trays, however, the cones should be screened, in order that no loose seed will be subjected to the heat. When the cones nearest the stovepipe are dry they should be removed, and the upper trays dropped down, while the empty ones should be refilled and inserted above.

When nearly all are open the cones should be removed from the drying room, thrashed thoroughly with a flail, and screened. The screen should have a $\frac{1}{2}$-inch mesh and a frame about 6 feet long by 3 feet wide. The seeds and débris which fall through it should then be rubbed through a final screen with a mesh of about $\frac{1}{6}$ inch. This will break off the seed wings and remove the larger particles of dirt and pitch. The seeds and finer particles which pass through the last screen should then be run through a fanning mill, which will remove all the wings and dirt and leave the clean seed ready to be sowed or stored. Each bushel of cones will yield from one-half pound to a pound of clean seed, running from 26,000 to 30,000 seeds to the pound.

Seeds may be stored over winter by inclosing them in a paper or cloth bag (not oiled) and suspending them in a cool, dry room with a free circulation of air. Cellars and stables are not good storage places. If thoroughly dry, seeds may also be stored in large, tight tin cans or in bottles, preferably in an unheated building.

THE FOREST NURSERY.

Where the area to be planted is small, it is better to purchase planting stock from dealers than to incur the trouble and expense of nursery culture. If, however, the area is so large that planting operations will extend over several years, stock may be raised at a considerable saving.

The size of the nursery depends upon the number of plants to be produced each year and the length of time the young trees are to be left in the beds. In most planting operations stock 3 years old should be used. To enable them to develop a strong and compact root system the seedlings should be transplanted when 2 years old from the beds in which the seed germinated to rows in another part

of the nursery, where they should remain a year before being set out in the field. Such stock is called "2–1" transplants. To plant 10 acres a year would call for an output of not over 15,000 of these, and the total nursery area required would be about 10 or 12 square rods.

The nursery should, if possible, be close to the planting site. A good, well-drained soil is essential. This should be preferably a rich sandy loam, and the seed beds, at least, should be heavily fertilized with well-rotted barn manure. A northern exposure is best, since it offers the least chance of damage from frost heaving and from drying winds. Water should be available for the stock in hot weather, and the nursery should be well fenced, preferably with woven wire.

To accommodate 15,000 seedlings two seed beds 12 feet long and 4 feet wide will usually be sufficient. It is well, however, to have an extra bed to provide against possible loss of seedlings from disease, frost heaving, or drought. The beds should run east and west, so that the shade from the lath frames over them will be well distributed through the day. In constructing the beds the ground, after being fertilized, should be well spaded, cleared of all débris, and the earth pulverized. Beds should be raised about 4 inches above the general surface of the ground, with their centers slightly higher than their edges, to secure good drainage.

As a protection against birds and small rodents the beds should be inclosed in wire netting of small mesh; one-third-inch mesh is the best. The netting should be cut in 6-inch widths and nailed on frames placed around the beds. The lower strip of the frame should be covered with earth to prevent entrance from beneath it. A cover of the same wire netting should fit snugly on the side frames.

When the wire screen is being fitted to the beds it is well to prepare lath shade frames, which will be needed as soon as the seedlings appear. These consist of frames made of 2 by 2 inch pine strips with 4-foot crosspieces at each end, across the top of which laths are nailed at intervals equal to their width.

When the wire screen is in place the bed should be thoroughly soaked with water to a depth of 6 inches and firmed and smoothed with a spade, roller, or board. It is then ready for the seed, which may be sown either broadcast or in drills. In many ways the former method is best. If the seed is good, about 10 ounces (17,500 seeds) should be sown on each bed, but if the quality is poor a correspondingly larger amount will be needed. Seed should be pressed into the soil with a clean, smooth hoe or spade. A layer of fine soil, not over one-eighth inch deep, should then be spread over the beds. A coal-ash sieve, or one with a mesh of about one-fourth inch, should be used. Beds should be sprinkled until the seeds germinate, and should be covered with both the wire and lath screens. The open spaces in the latter should be filled in with loose laths, while light

and air should be further excluded from the beds by tacking some light covering, like building paper, around the frames and banking earth about the bases.

Seed should not be sown in the beds until after the frost is out of the ground and all danger of freezing weather is past. Sowing may be done when garden vegetables are planted, but if delayed until too late the tender seedlings may succumb to heat. It is better, however, to sow too late than too early. Germination is normally very slow, and two or three months may elapse before it is completed. From every pound of fertile seed about 12,000 plants may be expected.

When the germination period is past the beds should be examined from time to time, and a few days after the seedlings have begun to appear the paper and the loose laths should be removed from the shade screens. Unless this is done there is danger of poor development and damping-off. The latter is a very dangerous fungus disease[1] which may destroy all the seedlings in a bed during the first year. It develops most rapidly in moist and shady places and in wet soil. Good preventives are thorough ventilation and drying out. For this reason the shade frames should be entirely removed from the beds on overcast or damp days. The wire screen should be left on at all times except when work is being done.

In dry weather the beds should be sprinkled lightly about sunset. The partial shade given by the lath frames is necessary only during the summer of the first year, during hot, dry days, to protect the tender seedlings from sun scald and wilting and the beds from drying out. While the frames should be used also to protect the seedlings from heavy rains, they should be removed afterwards to permit the soil to dry out.

Toward fall the shade frames should be removed permanently, in order that the seedlings may harden up for the winter. The wire screens may also be removed at that time. After the first fall of snow the seedlings should be covered with a thickness of burlap, which should be left on the beds until the following spring.

Little care is necessary during the second summer other than to keep weeds out and supply the seedlings with water during very dry weather. Ordinarily no protection against birds and rodents is needed, nor is it necessary to cover the 2-year old seedlings for the winter.

To secure 2–1 stock the seedlings should be transplanted in the spring of the third year. In doing this care should be taken not to injure the roots or stems. The spade should be forced deep enough into the ground to get to the bottom of the roots, and the soil which adheres should be carefully shaken off. The seedlings should either be

[1] Suggestions for the prevention of damping-off are given in Bureau of Plant Industry Circular 4, "The Treatment of Damping-off in Coniferous Seedlings," by Dr. Perley Spaulding.

transplanted at once or their roots protected by a cover of fresh earth. Even a brief exposure of the roots to sun and air will kill the plants. A transplant bed 4 by 40 feet in size will hold about 2,000 transplants, arranged in transverse rows 6 inches apart with the plants 2 inches apart in the row. With reasonable care in transplanting, each bed should furnish 1,500 young trees. If the transplants are to be kept 2 years in the beds, the space between the plants in the rows should be doubled, thus reducing the capacity of the bed to 1,000, with probably 750 seedlings available for planting. The soil in the transplant bed need not be as rich as that in the seedling beds. Unless the transplant beds are well drained, however, they should be raised about 4 inches above the paths, with not too steeply sloping edges. The seedlings should be carried to the transplant bed in a wheelbarrow, basket, or broad, flat frame, with their roots lightly covered with loose, fresh earth. The transplant beds themselves should be well watered before the plants are placed in them. To save time and insure regular spacing of the plants a transplant board is useful. One employed with success by C. R. Pettis, State Forester of New York, is described as follows:[1]

This board should be 4 feet 3 inches long and 5½ inches wide, with notches cut on both edges of the top side, either 2 or 4 inches apart, according to the required distance between plants in the row, but the first notch should be 3 inches from one end and the notches exactly opposite on both sides of the board. The board is held in place by two sharpened pins set in the board and projecting from the under side. The planting board is laid crosswise of the bed so that the first row of trees will be set on the line marking the end of the bed, and one end of the board will be against the string that marks the side of the bed. After this first row is planted the board is moved back, or toward the planters, and the far side of the board placed against the row of seedlings already planted and one end against the string as before. One plant is set at each notch and the work proceeds in this manner until the bed is filled. If care is taken to keep the end of the board even with the string along the side of the bed the plants in each bed will be in straight rows both ways. It costs no more to have this uniform arrangement and is an advantage in every way, especially since it aids cultivation and gives each tree equal advantage.

Two men to a transplant board, one at each end, can work to best advantage, and doing the work thoroughly should set out 500 plants per hour. A long, narrow trowel is the best tool to use, and care should be taken to make the holes sufficiently deep for the root system. Care must also be taken to put the roots into the hole in proper position and to see that the plants are set in the ground at the same depth that they were in the seed bed. The earth should be thoroughly packed around the roots. The foreman can easily see if the laborer has planted the seedlings at the proper depth, and by pulling can find out whether they are set firmly and are tight in the ground. It requires constant supervision to see that the soil around the roots has been packed properly. As soon as the planting is completed the bed should be leveled and the nursery cleaned up.

[1] See Forest Service Bulletin 76, "How to Grow and Plant Conifers in the Northeastern States." Similar planting boards are described and illustrated in the following articles: "New Tools for Transplanting Conifers," by William H. Mast, Forestry Quarterly, Vol. X, No. 1; and "The Yale Transplant Board," by J. W. Toumey, Forestry Quarterly, vol. IX, No. 4.

Transplant beds need thorough weeding during the summer, which can best be done when the ground is moist. The transplants should be watered well when set out, and again from time to time during the first week or so. After that, however, they need not be watered except during very dry weather. They need no covering during winter.

Two-year seedlings, 1 year transplanted, are probably best for cut-over lands with a thin ground cover, or old fields covered with low growth or grass. Younger stock, however, may sometimes be used in such places, and where this is possible the expense involved in the larger nursery and longer cultural operations can be saved. For example, a portion of the seedlings are sometimes removed from the seed-bed the spring after the seeds are sown and are transplanted after one year, and then set out in the field. Those left may be planted along with the 1–1 transplants directly in the field or they may be transplanted one year before being set out. In the latter case the final stock will consist of 1–2 and 2–1 transplants. For planting in situations where the ground cover is at all dense 2-year old seedlings, 2 or even 3 years transplanted, should be used.

PLANTING.

Seedlings for planting may be raised in the nursery, as just described, purchased from dealers,[1] or dug up in the woods. The cost of producing 10,000 or 20,000 3-year-old transplants every year will probably be close to $4 per thousand, and when good stock of the same age can be secured at a price not too far above this, it is usually better, in small operations, to purchase it. Wild seedlings may be used, but as a rule their root systems are straggling, and the plants lack the resistant qualities of transplants.

Planting is best done in the spring, as soon as the frost is out of the ground and before the buds of the young trees have begun to grow. Since the time is thus limited to from four to six weeks, planting should take precedence over nursery work.

If the planting site is near the nursery, the stock may be carried to it in the same way as from the seed to the transplant bed. Even greater care should be used, however, to prevent the roots from becoming the least bit dry. When the stock arrives at the planting site it should immediately be "heeled-in." If it is purchased stock and comes bundled, the bundles should be untied and loosened. Heeling-in consists in placing the plants in a thin layer along the sloping side of a ditch dug slightly deeper than the length of the

[1] A dangerous disease of white pine, the "blister rust," has recently been introduced into American nurseries from Europe. When buying stock for planting, the seller should be required to guarantee it to be free from this disease. The blister rust is discussed in detail in Bureau of Plant Industry Bulletin 206, "The Blister Rust of White Pine," by Dr. Perley Spaulding.

roots. The roots of the young plants should be carefully spread out and covered with fresh or moist earth, the ditch filled, and the soil packed by tramping and thoroughly soaked with water. When the planting is not to be done at once, the heeled-in stock should be shaded in some way, as by spreading boughs over it. The plants should be carried to their final destination in a basket or pail with their roots surrounded by a quantity of damp sphagnum moss or by pieces of wet burlap. The importance of keeping the roots moist and protected from the air can not be too strongly emphasized. Even a few minutes exposure will kill the plants, especially on hot, dry days. In the past it has been customary to transport the plants to the field in pails with their roots immersed in a puddle of clay or loam and water. While excellent results have been obtained by this means, it is now believed that puddling causes many of the fine rootlets to stick together and to interfere with each other, so that the death of many plants, especially in dry situations, can probably be traced to this practice. Fresh but not wet sphagnum moss is a convenient substitute and makes it possible to spread out the root fibers when the seedlings are planted. When possible, planting should be done on sultry or overcast days.

In planting, the men work in pairs, one man digging holes and the other setting the trees. The mattock is usually preferred to the spade for this work. The holes should be large enough to give room for the roots without crowding, and, especially on light soils, the plants should be placed slightly deeper than they were in the nursery. When making the hole, it is well to cut off and remove a thin slice of sod in order to avoid immediate competition of grass roots. The roots of the plants should be spread out and placed in as nearly a normal position as possible. This can be accomplished by lowering the plant until the base of the stem is close to the bottom of the hole and the roots are spread out horizontally. Fresh earth is then thrown in with the free hand. At the same time the plant is raised with the other hand until the base of the stem almost reaches the surface level. Instead of tramping the earth down solidly from above, it should be compressed from the sides by putting both hands simultaneously into the loose earth 2 or 3 inches on either side of the stem and compressing the closed fists strongly toward the plant. The empty spaces are then filled with earth, which is pressed firmly downward with the closed fists, care being used not to apply the pressure too near the central earth mass. Loose earth should then be thrown over the surface.[1] While this method is at first a little slow, it can be carried on with considerable speed after some practice.

[1] This method, devised and carried out with great success by the Belgian forester, Morris Kozesnik, is described and illustrated in the Proceedings of the Society of American Foresters, vol. IV, No. 2.

Where the soil and climatic conditions especially favor the growth of seedlings, the less expensive method of "slit planting" may be used. In this the roots of the seedling are dropped into a slit in the soil made by inserting a spade and slightly working it forward or backward. The soil is then packed about the roots by reinserting the spade 2 or 3 inches from the plant and closing the previous slit. The soil is then firmly pressed down with the foot. This method is a very rapid one, but the roots are left in a crowded and unnatural position, which may for years interfere with the thrift of the plant.

The number of trees which can be set out per day varies with the nature of the ground cover, the texture of the soil, the character of the labor employed, and the degree of care exercised in the work. On fresh loamy or sandy soils, without a low herbaceous ground cover, two capable workmen should be able to set out 1,000 of the 2–1 transplants a day. With unfavorable conditions, as when the ground is full of tough roots, the same men might plant only 500 seedlings.

The most common and probably the best spacing for white-pine transplants is 6 by 6 feet. In especially favorable situations, where growth will be rapid, a spacing of 8 by 8 feet may be used, while in less favorable ones the plants should be closer together, either 5 by 5 feet or 4 by 4 feet. The number of plants per acre spaced at different distances is shown in Table 18. Where pruning is to be practiced, a spacing of 10 by 10 feet, or 12 by 12 feet, has been recommended.

TABLE 18.—*Number of trees required to plant an acre, using rectangular method of spacing.*

Distance between the rows.	Number of trees when distance apart in the row is—				
	4 feet.	5 feet.	6 feet.	7 feet.	8 feet.
Feet.					
4	2,722	.....	.....	.....	.....
5	2,178	1,742	.....	.....	.....
6	1,815	1,452	1,210	.....	.....
7	1,556	1,244	1,037	888	.....
8	1,361	1,089	907	777	680

The cost of planting per thousand plants varies with the same factors which influence the daily rate of planting. The cost per acre varies with these and also with the number of seedlings planted per acre. Tables 19 and 20 give the cost per thousand and per acre, respectively, of planting stock costing $3, $4, and $6 per thousand when the average planting rate per man is 300, 500, and 600 plants per day, with different daily wage rates. The average planting rate is based on the total time consumed in the work, including digging up or unpacking transplants, carrying from nursery to field, heeling-in, etc.

TABLE 19.—*Total planting cost per thousand plants for planting stock of different values.*

Number planted per man per day.	Daily wage rate per man	Labor cost per thousand.	Total cost per thousand of stock and labor.		
			Planting stock $3 per thousand.	Planting stock $4 per thousand.	Planting stock $6 per thousand.
300	$1.50	$5.00	$8.00	$9.00	$11.00
	2.00	6.67	9.67	10.67	12.67
500	1.50	3.00	6.00	7.00	9.00
	2.00	4.00	7.00	8.00	10.00
600	1.50	2.50	5.00	6.50	8.50
	2.00	3.33	6.33	7.33	9.33

TABLE 20.—*Total planting cost per acre under different conditions.*

Number planted per man per day.	Daily wage rate per man.	Cost of planting stock per thousand.								
		Spacing 8 by 8 feet.			Spacing 6 by 6 feet.			Spacing 4 by 4 feet.		
		$3	$4	$6	$3	$4	$6	$3	$4	$6
300	$1.50	$5.44	$6.12	$7.48	$9.68	$10.89	$13.31	$21.78	$24.50	$29.94
	2.00	6.58	7.26	8.62	11.70	12.91	15.33	26.32	29.04	34.49
500	1.50	4.08	4.76	6.12	7.26	8.47	10.89	16.33	19.05	24.50
	2.00	4.76	5.44	6.80	8.47	9.68	12.10	19.05	21.78	27.22
600	1.50	3.40	4.42	5.78	6.05	7.87	10.29	13.61	17.69	23.14
	2.00	4.30	4.98	6.34	7.66	8.87	11.29	17.23	19.95	25.40

The tables bring out the fact that the spacing, more than any other factor, influences the acre cost of planting. The spacing of 4 by 4 feet requires so many trees per acre that, as a rule, its cost is prohibitive. The 6 by 6 plantation will vary in cost between $6 and $13 per acre, although when all incidental expenses of planting are figured it may in some cases exceed $15. A spacing of 8 by 8 feet is very desirable from the standpoint of cost, and on good soils with cool, moist exposure, the rapid growth of the trees may fully warrant it. In such cases the first thinning may be made later than with other spacings. While with the wide spacing the branches may grow a trifle larger, they will persist no more tenaciously than when the stand is denser. The saving in the initial cost may be later expended to good advantage in pruning. Moreover, in a widely spaced plantation there is room for the development of desirable broadleaf trees between the pines.

DIRECT SEEDING.

Under average conditions artificial sowing is less likely to be successful than planting, and in a number of cases has resulted in complete failure. There are, of course, notable exceptions, such as the Shaker plantation in north central Connecticut, where a very dense forest resulted from the broadcast sowing of pine seed along with

rye. One crop of rye was reaped and the land then abandoned to the pine.

While the initial expense of sowing may sometimes be less than that of planting, it is often greater, and the stand, even if moderately successful, will usually contain openings which must be planted up if a fully stocked stand is desired. In the long run the sowed stand may prove considerably more costly and at the same time inferior to the planted one. Sowing, however, is a relatively easy method of reproduction, and is the only way in which very large areas can be economically covered in a single season.

There are three methods of sowing seed direct: (1) broadcasting over the whole area, (2) sowing in strips, and (3) sowing in seed spots.

Broadcast Sowing.

Ordinarily, broadcast sowing offers little chance of success, except when the ground has been cultivated or burned over, or the seed raked in after sowing, for not only must there be a sufficient amount of moisture for germination, but the seedling must quickly get its rootlets into mineral soil. It is best to sow broadcast except where conditions are especially favorable, as when there is a very light ground cover partially exposing the mineral soil. Conditions such as these may be found on burned-over areas coming up to aspen, from which fire has removed part of the grass and litter, and shade is afforded the pine seedlings in early youth by the aspen trees. Ground covered with leaves of broadleaf trees is not a suitable site for broadcasting, since the leaves either prevent the seed from reaching the soil or smother the seedlings after they germinate. Sloping ground, where there is usually the least litter, with a north or east aspect, ordinarily offers the best site for broadcasting. It is on recently cultivated land, however, that broadcast sowing has been most successful. Here also the sowing can be combined cheaply with crop raising.

Until white-pine seed becomes cheaper, however, broadcast sowing is hardly justified from a financial standpoint. Five pounds of seed are necessary to broadcast an acre. With the price of seed at $2.25 per pound (cheaper at wholesale), the initial cost of sowing an acre will be $11.25. Results obtained in actual practice vary from total failure to a stand of several thousand seedlings per acre. Success depends chiefly upon whether the ground is properly prepared. A pound of seed sown in a nursery bed will produce from 10,000 to 15,000 seedlings, and the expense of producing and planting on an acre 1,210 two-year-old seedlings (6 by 6 spacing) will cost from $7 to $15, with a reasonable assurance of 80 per cent survival.

Sowing in Strips.

Under the strip method strips 6 to 8 feet wide are sown, gridironing the tract with blank spaces from 6 to 8 feet wide between. This method is cheaper than broadcasting since less seed is required per acre.

Sowing in Seed Spots.

The method of sowing in seed spots consists in sowing the seed in prepared spots at regular intervals. The sod is removed from a small spot, commonly about a foot in diameter, and a seed bed prepared in which from 5 to 15 seeds are planted. The work can be done with a hoe, and the planters kept in line by flags. Spots where the seed fails to germinate should be filled in the following year by transplanting from spots which have produced groups of seedlings. Conditions favorable for seed-spot sowing are the same as those for planting two-year-old seedlings; namely, where there is a light ground cover, as on old pasture land. Under the shade of hardwood sprouts or on moist ground there is little chance for success.

With the seed-spot method one man should sow an acre a day and use 1 pound of seed. With labor at $1.75 a day and seed at $2.25 a pound, the initial cost will be $4 per acre, with a cost for filling in the gaps to be added later on. In New York State a careful record of the expenditures for seed-spot planting indicates that $10 per acre is the average cost.[1]

Protection from Rodents.[2]

A large source of loss when seed is planted directly in the field comes about through its destruction by small rodents. To prevent this, small amounts of grain soaked in a solution of strychnia should be deposited over the area in the spring, some time in advance of the sowing. A formula for poisoning chipmunks, recommended by the Biological Survey, which has given good results, is the following:

Strychnia sulphate	1 ounce.
Saccharin	1 teaspoonful.
Gloss, or laundry starch	½ cupful.
Water	1 quart.
Barley	20 pounds.

Where mice as well as chipmunks are prevalent the following formula has proved effective:

Strychnia (alkaloid or sulphate)	1 ounce.
Saccharin	1 teaspoonful.
Melted tallow	1 pint.
Wheat	16 quarts.

[1] C. R. Pettis, Fifteenth Annual Report Forest, Fish, and Game Commission, State of New York.

[2] This subject is fully discussed in Biological Survey Circular 78, "Seed Eating Mammals in Relation to Reforestation," and in Forest Service Bulletin 98, "Reforestation on the National Forests."

The wheat should be warmed in a metal saucepan or similar receptacle and the saccharin and strychnia pulverized and sprinkled over it. The melted tallow should then be poured in, and the mixture stirred until every wheat kernel is coated.

In depositing the poisoned grain it must be put out of the reach of birds. This can be done by placing it in cavities among small piles of stones or under roots or logs, or in burrows of animals. If this is not practicable the grain can be covered with pieces of bark, boards, or flat stones, with a low runway left beneath. Barley is usually attractive to rodents and is at the same time the grain least relished by birds.

PROTECTION.

FIRE.[1]

Unlike loblolly pine of the South, or the red pine with which it is often associated, white pine has a thin bark during the first 30 or 50 years of its life, which affords but slight protection from fire. Young growth, with its thin bark and delicate foliage, is usually killed at once by fires which would do little damage to thick-barked trees. When white pine has reached an age of from 40 to 60 years, however, and has formed a thick, corky bark, it is comparatively safe from direct injury by surface fires. Yet if the fire reaches the crown and scorches the branches the tree is certain to die. Young pines also are often killed in this way. Besides its direct damage, fire offers a way for insects and fungi to enter the trees.

Measures usually included under fire protection aim (1) to prevent fires from starting, (2) to detect fires as soon as possible after they start, and (3) to extinguish them when once started in the shortest possible time.

Briefly, fire prevention consists in (1) suitable legislation regarding fires, (2) destroying and rendering less dangerous inflammable material, and (3) constructing efficient fire lines to prevent the spread of flames.

Most of the Eastern States already have excellent fire laws, which when supported by an educated public sentiment and properly inforced tend to reduce the fire risk to the minimum. These laws usually provide against lighting fires during danger seasons, and impose penalties for damage from fire which may be allowed to escape at any time. The laws usually contain special provision for the use of spark arresters on locomotives and of oil instead of coal for fuel in regions where the risk is great.

[1] For a full discussion of forest fires and their prevention, see Forest Service Bulletin 82, "Protection of Forests from Fire," by Henry S. Graves; also Forest Service Bulletins 111, "Lightning in Relation to Forest Fires," and 117, "Forest Fires; Their Causes, Extent, and Effects, with a Summary of Recorded Destruction and Loss," by Fred G. Plummer.

The disposal of slash is important as a preventive measure. The best time to destroy brush or débris is while logging is in progress. With the aid of one extra swamper the burning of brush can be cheaply and effectively done by the logging crew. The best time to burn brush is during a wet season, preferably in winter when snow is on the ground. The cost of burning depends upon the character of the stand and the cost and efficiency of labor. Wide-topped trees, the type known as "cabbage pines," have heavy crowns and large limbs, which cost more per thousand board feet to burn than the brush from smaller crowned trees grown in pure, fully stocked stands. In mixed stands of white pine and other species, the burning of white-pine slash is more expensive than in pure stands. In mixed stands of red and white pine, in the Lake States, brush has been disposed of while the logging is in progress for 12 cents per thousand board feet. In many cases, however, it will cost much more than this.

When logging is done in a dry season the brush should be piled when the trees are cut, but not burned until moister conditions prevail. In piling, the tops should be thrown to the center of the piles and the smaller branches placed at the bottom, with successively larger material laid above. This makes a compact pile, easy to burn. The size of the piles will depend upon the amount of material to be disposed of and the available space. Small piles are safer than large ones, a convenient size being 10 feet across and 6 feet high. The piles should not be within 20 feet of standing trees or placed in a way to obstruct the skidding of logs. In general, the cost of piling and burning white-pine slash will probably range from 25 to 50 cents per thousand board feet of lumber cut.

The slash should not be burned in windrows, since unless the weather and moisture conditions are favorable there is danger of starting a general conflagration. Often, moreover, the windrows cover a large percentage of the total area, and when they are burned the greater part of the seed which has fallen during logging will be destroyed.

While the scattering of slash is not advisable where there is danger from fire, it may, wherever conditions permit, be made to serve an important function by protecting the soil and small seedlings from drought and frost. In scattering slash, however, no tops should be left propped up on the ground by their side branches. All branches should be lopped and the brush made to lie flat on the ground. In close stands, where burning is impracticable, scattering is the best means of disposing of slash. It is also perhaps the best method in moist situations where the branches will decay rapidly.

For the prevention of fire on comparatively small tracts a simple system of fire lines, supplemented by patrol at intervals during the danger season, is probably sufficient. On large tracts a system

Brush Piled for Burning; Clear Cutting, Leaving 5 Per Cent of the Stand for Seed Trees. Minnesota.

of roads and trails is exceedingly useful and in many cases essential, since they serve as fire lines and at the same time afford easy access to any part of the area. A road only 6 feet wide, from which all litter and vegetation have been removed, can be made an effective barrier against a severe ground fire, while a single furrow of earth or a cleared trail will often check a surface or grass fire. Where the risk of fire is very great, as in extensive pine forests, or where valuable property is to be protected, special fire lines may have to be constructed. The most effective kind is a fully cleared strip, from which trees, underbrush, and all débris and litter have been removed down to the mineral soil. Ordinarily a width of from 6 to 15 feet is sufficient, though sometimes a greater width may be necessary. The cost of constructing a fire line for second-growth woodlands ranges from $30 to $50 a mile.

Existing roads and trails can, of course, serve as fire lines. To be really effective, however, they must be cleared of all underbrush and débris. In addition, fire lines should be established at strategic points, such as boundary lines and along hill crests. Especially dangerous points, such as along a railroad or where old slashings are next to young reproduction of valuable timber, should also be protected by special fire lines. In the Northeastern States, where the woodlands are in small blocks broken by many roads and trails and numerous houses, the presence of a forest fire is soon detected. The farmer can act as his own guard, and by proper care in clearing out his roads and disposing of his brush make his woodlot comparatively safe.

For observing wide stretches of uninhabited woodland, forest-fire lookout stations on elevated points have been established in several of the States with good results. The watchman in charge is provided with a map of the surrounding country, a telescope to detect a fire, and a range finder to locate its position. As soon as a fire is observed he telephones for aid. During the dry season, from April 1 to October 1, a patrol system is very essential for the protection of wide stretches of sparsely settled country.

An effective fire-fighting outfit should include shovels, rakes, grub hoes, axes, ropes, and collapsible pails. The implements should be kept in a convenient place ready for immediate use.

The various methods of fighting fires have been developed according to the needs of a particular locality. For checking ground fires which smoulder and burn stubbornly where there are large accumulations of duff, the digging of trenches with shovels or grub hoes has been found very effective. In sandy land, free from rocks, sand may be used effectively in extinguishing fire. Loose loam is also good for the purpose, though not as effective as sand, but heavy soil that forms clods is of little value. Some surface fires in dry leaf litter or in short grass among scattered tree growth may be beaten out with

gunny sacks, green branches, or some similar article. Chemical extinguishers are useful wherever available. Where the woodland is much broken up by roads, the fire-fighting apparatus may be carried in a light, four-wheeled wagon. Such an outfit is especially useful in well-settled regions where fire endangers buildings.

A crown fire, that is, one burning in the tops of the trees, is the most serious. It is always accompanied by surface fires. An ordinary crown fire will jump a wide fire line, and has often been known to cross wide rivers. Under such circumstances back-firing becomes absolutely necessary. It can also be done where other methods of fire fighting can not be used, or where they fail to stop a fire. It should, however, be a last resource.

STOCK.

A pine forest is less liable to injury from cattle than is one composed of deciduous trees. Old pastures often grow up to a fair stand of pine even while being grazed, cattle preferring the broadleaf species. If it is desired to raise timber, however, cattle should be excluded for four or five years, or until the young growth obtains a good start, since they are certain to do more or less injury to the growing trees.

White pine when injured shows considerable powers of recuperation, as exhibited in the ready reestablishment of a broken leader and the healing of wounds. In the latter case the prolific resin exudations assist by keeping out water and fungi.

WHITE PINE WEEVIL.

There are a number of insect and fungous enemies of white pine which may do more or less damage to the trees. This bulletin treats briefly of but one of these sources of injury, the white pine weevil,[1] *Pissodes strobi*, an insect which does a good deal of damage to white pine practically throughout its range, but especially in the East. The weevil is a reddish-brown beetle, about one-quarter of an inch in length, which, like all weevils, has a proboscis or snout. It always attacks the terminal shoot or leader of the tree and kills back the growth of one or two years. Though a new leader begins to develop the next year, through one of the side branches assuming a vertical position, there remains a more or less pronounced crook. Crooked branches, when of fair size, often saw out surprisingly large amounts of round-edged box board lumber, but the loss in badly infested stands is nevertheless great. The damage shortens the length of boards which can be sawed out and, of course, interferes with subsequent growth in quality. This is especially the case when, as often happens, the same trees are repeatedly attacked.

[1] The white pine weevil, its habits and methods of control, are described in Circular No. 90, of the Bureau of Entomology, by A. D. Hopkins.

According to Dr. Hopkins, the adult overwintered beetles are active during the month of May, and the eggs are deposited in the bark of the terminal of the preceding year's growth. Small whitish grubs hatch from these eggs, feed on the inner bark, and thus cause the death of the terminal. When the grubs are full grown they transform to pupæ early in July in chip cocoons in the outer wood or pith of the terminal, and the adults will begin to emerge from the terminals during the last week in July, and practically all will be out by the 15th of September.

The terminals which are infested with the medium to maturing stages of the weevil are easily recognized during the latter part of June and first part of July by the wilting of the new terminal and branches on the last year's terminals, and this is the time the terminals should be removed in order to destroy the brood.

Weevil damage is most common, and always most serious, in trees less than 30 feet high. Protective measures must be undertaken, therefore, when the stand is young. Whenever an infestation appears all the pine tops which show it should be cut off during June and July, before the beetles have escaped. These can be burned, but since they often contain minute insect parasites which are themselves valuable agents in resisting the increase of the weevils, it is best to treat them according to the method suggested by Dr. A. D. Hopkins, of the Bureau of Entomology. This consists in placing the infested tops in a tight box, barrel, or preferably a metal can with but one opening covered with ordinary fly-screen netting. This permits the escape of the small parasites, but confines the weevils. The receptacle, if of wood, should be examined from time to time to see that no weather checks or cracks develop which would allow the weevils to escape. It will take more than one season to exterminate weevils should they appear, and young stands should, wherever possible, be examined every year during the months of June and July.

Occasionally two side branches instead of one will replace the destroyed leader, resulting in a forked tree. To prevent this, all but one side branch of the upper whorl—the thriftiest where there is a difference—should be cut off even with the main stem. Where trees have already started to fork one of the forks should be removed in the same manner.

APPENDIX.

Height Growth in Germany.

Table 21 shows the height growth of white pine in German plantations.

Table 21.—*Height growth of white pine in German plantations.*[1]

Age.	Height.		Age.	Height.	
Years.	*Meters.*	*Feet.*	*Years.*	*Meters.*	*Feet.*
10	3–5	10–16	60	22–24	72–79
20	8–10	26–33	70	25–27	82–89
30	12–14	39–46	80	28–29	92–95
40	16–18	52–59	90	30–31	98–102
50	19–21	62–69	100	32–33	105–108

[1]Hemple und Wilhelm, "Die Bäume und Sträucher des Waldes," pp. 182–187.

Volume Tables.

Table 22 shows the volume in board feet by the Scribner rule for trees of various diameters and height in the Lake States. It is based on measurements of a large number of trees in northern Minnesota, made under the personal supervision of Mr. E. S. Bruce, of the Forest Service. Deductions for defect were made in the field by expert lumbermen.

Table 22.—*Volume in board feet of white pine in northern Minnesota.*

Diameter, breast-high.	Height of tree (feet).											Diameter of top inside bark.	Basis
	40	50	60	70	80	90	100	110	120	130	140		
	Volume (board feet).												
Inches.												*Inches.*	*Trees.*
8	20	25	30	35	45							6	129
9	25	35	45	50	60							6	220
10	35	45	55	65	75	90						6	248
11	40	55	65	80	95	110	125					7	279
12	50	65	80	95	115	130	150					7	279
13	55	75	95	115	135	155	175					7	271
14	65	90	110	135	155	180	205	230				7	234
15		105	130	155	180	210	235	265				7	246
16		120	150	180	210	245	275	300				7	222
17			170	205	240	280	310	345				8	259
18			190	235	275	315	355	390				8	202
19			215	265	310	355	400	440				8	190
20				295	350	400	450	495	535			9	163
21				330	390	450	500	560	600			9	155
22				370	430	500	560	620	670			9	118
23					480	550	620	680	730			10	106
24					530	610	680	750	810	860	920	10	85
25					590	670	750	820	880	950	1,020	10	99
26					650	730	810	890	960	1,040	1,110	11	68
27					710	800	870	960	1,040	1,130	1,210	11	63
28					780	860	940	1,030	1,120	1,220	1,310	11	56
29						930	1,000	1,100	1,200	1,310	1,410	12	37
30						1,000	1,070	1,180	1,280	1,400	1,510	12	37
31							1,140	1,250	1,370	1,490	1,600	12	36
32							1,210	1,330	1,450	1,570	1,700	12	24
33							1,280	1,400	1,530	1,660	1,790	13	23
34							1,350	1,480	1,610	1,750	1,880	13	15
35							1,420	1,550	1,690	1,830	1,970	13	12
36							1,490	1,630	1,770	1,910	2,060	13	8
37							1,560	1,700	1,850	2,000	2,150	13	4
38							1,630	1,780	1,930	2,080	2,240	13	3
39								1,860	2,020	2,170	2,330	13	6
40								1,940	2,100	2,260	2,420	14	3
Total													3,899

Height of stump, 0.5–3.5 feet. Volume computed by the Scribner rule.

Table 23 shows the volume in board feet by the Doyle-Scribner rule for trees of various diameters and height in the Southern Appalachian Mountains. The figures were compiled under the direction of Walter Mulford.

TABLE 23.—*Volume in board feet of white pine in the Southern Appalachians.*

Diameter, breast-high.	Height of tree (feet).												Diameter of top inside bark.	Basis.
	60	70	80	90	100	110	120	130	140	150	160	170		
	Volume (board feet).[1]													
Inches.													*Inches.*	*Trees.*
12	40	50	60	75									8.5	6
13	60	70	80	95									9.0	2
14	80	90	100	115	135								9.4	7
15	100	110	125	140	160								9.9	12
16	125	135	150	165	185	230							10.2	20
17	155	165	180	195	220	270							10.6	25
18	185	200	215	230	260	310	360						10.9	25
19	225	240	250	270	300	355	410						11.2	37
20	265	280	295	320	350	400	460						11.5	37
21	310	325	345	370	405	455	515	585					11.8	49
22	355	375	395	425	460	510	565	645					12.1	46
23		425	455	485	515	565	625	710	820				12.4	42
24		480	510	540	580	625	685	775	895	1,040			12.7	48
25		535	575	605	645	690	755	845	980	1,140			13.0	53
26		590	640	675	710	755	820	925	1,060	1,240			13.2	65
27		650	710	745	780	825	895	1,010	1,150	1,345			13.5	55
28		710	780	815	850	900	975	1,095	1,250	1,455	1,680		13.7	55
29			855	890	925	975	1,060	1,190	1,350	1,570	1,785		14.0	54
30			930	965	1,005	1,055	1,145	1,290	1,465	1,680	1,895		14.3	52
31			1,010	1,050	1,085	1,140	1,240	1,390	1,585	1,795	2,005		14.6	49
32			1,095	1,130	1,165	1,230	1,335	1,495	1,695	1,910	2,120	2,300	14.8	49
33			1,180	1,220	1,255	1,325	1,445	1,605	1,815	2,035	2,240	2,426	15.1	42
34			1,270	1,315	1,355	1,430	1,560	1,720	1,925	2,155	2,365	2,550	15.4	40
35				1,415	1,460	1,535	1,665	1,835	2,045	2,290	2,505	2,690	15.7	35
36				1,520	1,555	1,655	1,770	1,945	2,175	2,435	2,650	2,855	16.1	32
37					1,660	1,755	1,880	2,065	2,310	2,580	2,810	3,040	16.4	28
38						1,850	1,985	2,185	2,450	2,730	2,980	3,230	16.9	20
39						1,945	2,095	2,315	2,600	2,885	3,165	3,450	17.3	19
40						2,050	2,195	2,430	2,750	3,050	3,345	3,655	17.8	24
Total.														1,028

[1] Volume computed by the Doyle-Scribner rule.

Table 24, based on data collected by Louis Margolin, shows the volume, in board-feet, for trees of various diameters and heights in southern New Hampshire. It is based on the actual mill cut of the trees and therefore runs higher than if it were based on log scale. This should be borne in mind in using the table.

TABLE 24.—*Volume, in board-feet, of second-growth white pine in southern New Hampshire.*

Diameter breast-high.	Height of tree (feet).										Basis.
	30	40	50	60	70	80	90	100	110	120	
	Volume (board feet).[1]										
Inches.											*Trees.*
5	8	12	15	.....	.....	.....	.....	.....	.....	.....	7
6	13	20	23	27	29	.....	.....	.....	.....	.....	41
7	18	28	34	39	44	.....	.....	.....	.....	.....	75
8	24	36	45	53	62	.....	.....	.....	.....	.....	128
9	32	44	56	69	81	93	.....	.....	.....	.....	156
10	41	53	70	85	102	119	138	.....	.....	.....	177
11	.....	63	84	103	126	147	168	.....	.....	.....	164
12	.....	73	100	125	151	177	200	228	245	.....	146
13	.....	84	117	148	180	210	238	270	293	.....	137
14	.....	95	137	173	210	243	277	312	348	.....	91
15	.....	105	158	200	241	282	321	362	406	.....	61
16	.....	.....	181	230	277	323	370	415	470	.....	88
17	.....	.....	209	261	313	368	421	471	540	.....	70
18	.....	.....	238	297	352	411	475	531	610	688	68
19	.....	.....	270	336	393	460	530	598	682	763	44
20	.....	.....	302	379	436	506	583	660	750	840	35
21	.....	.....	.....	425	480	553	634	720	820	918	23
22	.....	.....	.....	.....	522	597	681	779	887	990	16
23	.....	.....	.....	.....	566	639	727	834	958	1,065	19
24	.....	.....	.....	.....	.....	674	769	889	1,030	1,135	9
25	.....	.....	.....	.....	.....	706	809	942	1,105	.....	12
26	.....	.....	.....	.....	.....	737	846	994	1,180	.....	11
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,578

[1] The volumes are for actual saw cut. Sixty per cent of the lumber sawed was round-edged and 40 per cent squared, 70 per cent 1-inch boards, and 30 per cent 2½-inch plank.

Table 25, from Forest Mensuration of White Pine in Massachusetts, by Harold O. Cook, shows the volume, in board-feet, of second-growth white pine of various diameters and heights in that State. It is based on the actual mill cut of the trees. Tables 26 and 27 show the volume in cubic feet for New Hampshire and Massachusetts, respectively. Table 28 gives volumes in cordwood for Massachusetts.

TABLE 25.—*Volume, in board feet, of second-growth white pine in Massachusetts.*

Diameter breast-high.	Height of tree (feet).							
	30	40	50	60	70	80	90	100
	Volume (board feet).[1]							
Inches.								
5	10	.....	.....	.....	.....	.....	.....	.....
6	15	20	30	.....	.....	.....	.....	.....
7	20	30	40	50	65	.....	.....	.....
8	25	35	50	65	85	.....	.....	.....
9	30	45	60	80	105	115	.....	.....
10	40	55	75	95	125	145	.....	.....
11	.....	65	90	115	145	170	200	230
12	.....	75	105	135	165	200	230	260
13	.....	85	120	155	190	235	260	295
14	.....	100	140	175	215	265	310	335
15	.....	115	160	200	245	300	340	375
16	.....	.....	180	230	275	335	380	420
17	.....	.....	.....	260	310	370	425	470
18	.....	.....	.....	295	350	410	475	530
19	.....	.....	.....	335	390	455	530	600
20	.....	.....	.....	380	435	505	580	660
21	.....	.....	.....	.....	480	550	635	720
22	.....	.....	.....	.....	520	595	680	780
23	.....	.....	.....	.....	565	640	730	835
24	.....	.....	.....	.....	600	690	780	890
25	.....	.....	.....	.....	645	740	830	940
26	.....	.....	.....	.....	.....	.....	885	995
27	.....	.....	.....	.....	.....	.....	940	.....

[1] The volumes are for actual saw cut—circular saw—with ⅛-inch kerf. The logs were scaled to a minimum top diameter of 4 inches. The stump height was 6 inches.

TABLE 26.—*Volume in cubic feet of second-growth white pine in southern New Hampshire.*[1]

Diameter breast-high.	Height of tree (feet.)										Total basis.
	30	40	50	60	70	80	90	100	110	120	
	Total volume, including bark, stump, and top (cubic feet).										
Inches.											*Trees.*
5	2.3	3.0	3.6	.....	.....	.....	.....	.....	.....	.....	7
6	3.0	4.3	5.1	6.0	6.5	.....	.....	.....	.....	.....	41
7	4.1	5.7	6.9	8.2	9.2	.....	.....	.....	.....	.....	75
8	5.4	7.1	8.8	10.5	12.2	13.9	15.8	.....	.....	.....	128
9	6.9	8.8	10.9	13.0	15.4	17.8	20.2	.....	.....	.....	156
10	8.6	10.5	13.1	15.8	18.9	21.9	25.0	.....	.....	.....	177
11	.....	12.3	15.5	18.7	22.5	26.1	29.9	.....	.....	.....	164
12	.....	14.3	18.0	22.0	26.4	30.8	35.0	40.1	45.9	.....	146
13	.....	16.3	20.7	25.3	30.4	35.4	40.1	45.8	52.0	.....	137
14	.....	.....	23.7	29.1	34.8	40.2	45.8	51.7	58.8	.....	89
15	.....	.....	27.0	33.1	39.2	45.3	51.9	58.0	65.8	.....	61
16	.....	.....	30.7	37.5	44.3	51.0	58.1	65.1	73.7	.....	88
17	.....	.....	35.0	42.3	49.9	57.0	65.1	73.1	82.5	.....	68
18	.....	.....	40.0	47.6	55.5	63.9	72.2	82.0	92.1	104.2	68
19	.....	.....	.....	53.0	60.2	70.9	80.0	91.0	102.1	114.8	43
20	.....	.....	.....	.....	67.1	78.1	88.1	100.2	112.2	125.6	34
21	.....	.....	.....	.....	73.1	85.7	96.7	109.2	122.1	136.3	21
22	.....	.....	.....	.....	79.1	93.1	105.3	118.1	131.7	146.7	16
23	.....	.....	.....	.....	.....	101.0	113.6	127.0	140.5	156.1	18
24	.....	.....	.....	.....	.....	108.6	121.8	135.8	149.8	165.5	8
25	.....	.....	.....	.....	.....	115.8	129.8	144.2	159.0	174.6	12
26	.....	.....	.....	.....	.....	122.7	137.8	153.1	168.5	183.2	11
Total.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,568

[1] From data collected by Louis Margolin, Forest Service, in cooperation with the State of New Hampshire.

TABLE 27.—*Volume in cubic feet of white pine in Massachusetts.*[1]

Diameter breast-high.	Height of tree (feet).						
	30	40	50	60	70	80	90
	Volume (cubic feet).						
Inches.							
5	1.8	.....	.....	.....	.....	.....	.....
6	2.6	3.3	4.3	.....	.....	.....	.....
7	3.4	4.4	6.1	7.7	.....	.....	.....
8	4.5	6.0	7.8	9.8	12.0	.....	.....
9	5.9	7.7	10.0	12.0	15.0	.....	.....
10	.....	9.6	12.0	15.0	17.9	20.9	.....
11	.....	11.6	14.6	17.9	21.4	24.9	28.7
12	.....	13.9	17.6	21.1	25.3	29.8	33.7
13	.....	16.2	20.4	24.8	29.2	34.7	38.7
14	.....	.....	23.7	28.7	32.5	39.6	43.6
15	.....	.....	26.8	32.6	37.9	44.5	49.5
16	.....	.....	30.5	36.5	42.3	49.8	55.9
17	.....	.....	.....	40.3	47.2	56.7	62.3
18	.....	.....	.....	44.6	52.6	61.5	69.1
19	.....	.....	.....	49.0	57.9	67.8	76.9
20	.....	.....	.....	52.9	63.2	74.7	84.8
21	.....	.....	.....	.....	69.1	82.0	92.6
22	.....	.....	.....	.....	74.9	89.3	101.4
23	.....	.....	.....	.....	81.3	98.1	110.8
24	.....	.....	.....	.....	87.1	104.9	119.0
25	.....	.....	.....	.....	94.0	112.6	128.8

[1] From "Forest Mensuration of White Pine in Massachusetts," by Harold O. Cook. The volumes are for the portion of the tree between a 6-inch stump and a minimum top diameter of 4 inches, and include bark.

TABLE 28.—*Merchantable volume in cords, and number of trees per cord, for white pine in Massachusetts.*[1]

Diameter breast-high.	Height of tree (feet).													
	30		40		50		60		70		80		90	
	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.
Inches.	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*
5	0.03	33.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.03	33.3	0.04	25.0	0.05	20.0	.....	.....	.....	.....	.....	.....	.....	.....
7	.04	25.0	.05	20.0	.07	14.3	0.09	11.1	.....	.....	.....	.....	.....	.....
8	.05	20.0	.07	14.3	.09	11.1	.11	9.1	0.13	7.7	.....	.....	.....	.....
9	.07	14.3	.09	11.1	.11	9.1	.13	7.7	.16	6.3	.....	.....	.....	.....
10	.....	.....	.11	9.1	.13	7.7	.16	6.3	.19	5.3	0.22	4.5	.....	.....
11	.....	.....	.13	7.7	.16	6.3	.19	5.3	.23	4.3	.26	3.8	0.30	3.3
12	.....	.....	.15	6.7	.19	5.3	.22	4.5	.27	3.7	.31	3.2	.35	2.9
13	.....	.....	.17	5.9	.22	4.5	.26	3.8	.31	3.2	.36	2.8	.40	2.5
14	.....	.....	.....	.....	.25	4.0	.30	3.3	.34	2.9	.41	2.4	.45	2.2
15	.....	.....	.....	.....	.28	3.6	.34	2.9	.40	2.5	.46	2.2	.51	2.0
16	.....	.....	.....	.....	.32	3.1	.38	2.6	.44	2.3	.52	1.9	.58	1.7
17	.....	.....	.....	.....	.....	.....	.42	2.4	.49	2.0	.58	1.7	.64	1.6
18	.....	.....	.....	.....	.....	.....	.47	2.1	.55	1.8	.64	1.6	.71	1.4
19	.....	.....	.....	.....	.....	.....	.51	2.0	.60	1.7	.70	1.4	.79	1.3
20	.....	.....	.....	.....	.....	.....	.55	1.8	.66	1.5	.77	1.3	.87	1.2
21	.....	.....	.....	.....	.....	.....	.....	.....	.72	1.4	.85	1.2	.95	1.1
22	.....	.....	.....	.....	.....	.....	.....	.....	.78	1.3	.92	1.1	1.04	.96
23	.....	.....	.....	.....	.....	.....	.....	.....	.84	1.2	1.01	1.0	1.13	.88
24	.....	.....	.....	.....	.....	.....	.....	.....	.90	1.1	1.08	.92	1.22	.82
25	.....	.....	.....	.....	.....	.....	.....	.....	.97	1.0	1.16	.86	1.32	.76
26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.42	.70
27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.51	.66

[1] From "Forest Mensuration of White Pine in Massachusetts," by Harold O. Cook. The volumes, which were scaled by the Humphrey caliper rule for stacked cordwood, include bark, and are for the portion of the tree between a 6-inch stump and a minimum top diameter of 4 inches.

TABLE 29.—*Log rule for second-growth white pine.—Southern New Hampshire.*[1]

[Cut into both square and round-edged boards; circular saw, ¼-inch kerf.]

Diameter inside bark at small end of log.	Length of log (feet).			Basis (number of logs measured).
	10	12	14	
	Volume.			
Inches.	*Board feet.*	*Board feet.*	*Board feet.*	*Logs.*
3	5	7	9	167
4	8	10	12	429
5	13	15	17	530
6	18	21	24	606
7	24	28	33	613
8	30	36	42	542
9	38	46	52	456
10	47	56	65	395
11	56	68	80	290
12	66	81	97	248
13	77	96	115	202
14	89	112	134	168
15	102	130	155	144
16	.....	149	176	104
17	.....	169	198	97
18	.....	189	222	64
19	.....	211	247	40
20	.....	235	275	41
21	.....	260	304	17
22	.....	284	333	11
23	.....	.....	364	9
24	.....	.....	398	4
Total.	.....	.....	.....	5,177

[1] Prepared by Louis Margolin, Forest Service, in cooperation with the State of New Hampshire. Sixty per cent of the lumber sawed was round-edged and 40 per cent squared; 70 per cent 1-inch boards and 30 per cent 2½-inch plank.

Thickness of Bark.

Table 30 shows the thickness of bark on a radial section for white pine of various diameters in the Southern Appalachians. It also applies very generally throughout the tree's range.

Table 30.—*Thickness of bark—Southern Appalachians.*[1]

Diameter breast high.	Thickness of bark.	Diameter breast high.	Thickness of bark.	Diameter breast high.	Thickness of bark.	Diameter breast high.	Thickness of bark.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	0.14	11	1.20	21	2.10	31	2.94
2	.28	12	1.30	22	2.20	32	3.04
3	.40	13	1.38	23	2.28	33	3.16
4	.52	14	1.44	24	2.36	34	3.28
5	.64	15	1.54	25	2.44	35	3.40
6	.74	16	1.64	26	2.52	36	3.50
7	.86	17	1.72	27	2.60	37	3.64
8	.96	18	1.84	28	2.68	38	3.76
9	1.02	19	1.94	29	2.76	39	3.90
10	1.10	20	2.02	30	2.86	40	4.04

[1] From measurements taken under the direction of F. E. Olmsted.

Yield Tables.

Table 31 shows the average yield per acre of white-pine stands of various ages in the Lake States. The trees were scaled by the Scribner Decimal C rule, and the figures are an average of a large number of acres. The figures are for virgin forest and not for second growth, and for this reason are greatly below the yield given for second-growth white pine in Table 6, page 23.

Table 31.—*Yield per acre, virgin forest—Minnesota.*[1]

Age.	Yield per acre.	Age.	Yield per acre.	Age.	Yield per acre.	Age.	Yield per acre.
Years.	*Board feet.*	*Years.*	*Board feet.*	*Years.*	*Board feet.*	*Years.*	*Board feet.*
50	8,000	90	23,500	130	46,000	170	70,300
60	12,500	100	28,000	140	53,000	180	75,500
70	16,700	110	33,500	150	59,300		
80	20,000	120	39,700	160	65,000		

[1] Data collected by H. H. Chapman. Computed by Scribner Decimal C rule.

Tables 32 and 33 show the yield per acre, in cords, of pure stands of second growth white pine in New England.

Table 32.—*Yield of fully stocked stands of second-growth white pine in New England.*[1]

Age of stand.	Average height.	Total trees per acre.	Merchantable trees per acre.	Yield per acre.	Age of stand.	Average height.	Total trees per acre.	Merchantable trees per acre.	Yield per acre.
Years.	*Feet.*	*Number.*	*Number.*	*Cords.*	*Years.*	*Feet.*	*Number.*	*Number.*	*Cords.*
10	5	2,220	.....	.....	40	54	690	540	38
15	9	1,700	.....	.....	45	62	510	460	45
20	14	1,600	.....	.....	50	68	400	380	53
25	22	1,310	400	11	55	72	300	300	65
30	32	1,090	510	21	60	76	260	260	80
35	45	885	620	30					

[1] From "The Natural Replacement of White Pine on Old Fields in New England," by S. N. Spring, Bulletin 63, Forest Service.

TABLE 33.—*Yield per acre of second-growth white pine in Massachusetts.*[1]

Age.	Quality I.			Quality II.			Quality III.		
	1-inch boards, in board feet.	Cords.	Cubic feet.	1-inch boards, in board feet.	Cords.	Cubic feet.	1-inch boards, in board feet.	Cords.	Cubic feet.
Years.									
25	10,825	25.1	2,080	6,750	16.4	1,300	3,975	10.8	750
30	19,900	44.0	3,750	12,500	31.2	2,740	7,500	18.2	1,400
35	31,150	60.4	5,420	24,400	49.0	4,375	16,950	35.8	3,035
40	40,650	70.6	6,590	32,800	58.0	5,300	25,200	46.2	4,080
45	49,350	78.0	7,420	40,600	64.8	6,075	32,100	51.8	4,785
50	55,150	84.2	8,035	46,500	70.0	6,725	37,550	56.6	5,475
55	59,650	89.2	8,575	50,550	74.8	7,200	42,100	60.8	6,015
60	63,600	93.4	9,075	53,200	79.2	7,655	44,550	64.6	6,340
65	67,050	97.2	9,550	56,600	83.0	8,050	46,150	68.4	6,550

[1] From "Forest Mensuration of the White Pine in Massachusetts," by Harold O. Cook. Based on measurements of 177 sample plots, one-quarter and one-eighth acre in size, in stands of different ages and qualities. Yields scaled by the use of volume tables 24, 26, and 27.

RELATION OF TAXES AND OTHER COSTS TO THE STUMPAGE VALUE AND THEIR EFFECT UPON LENGTH OF ROTATION.

Table 34, which is based on the stumpage prices in Table 11 and the cost data in Tables 12 and 13, gives the proportion of the taxes and other expenses to the stumpage value, and shows how the expenses, distance of haul, interest rate, and site quality affect the length of the financial rotation.

TABLE 34.—*Taxes and other expenses in per cent of the stumpage value, where distance from stand to local market permits a daily haul of 1,000 and 3,000 board feet of lumber per team.* (*See p.* 31.)

Interest rate.	Age.	Quality.	Daily haul per team=1,000 board feet.				Daily haul per team=3,000 board feet.			
			Taxes.	Other expenses when cost of formation is—			Taxes.	Other expenses when cost of formation is—		
				$0	$6	$12		$0	$6	$12
	Years.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
4 per cent..	50	I	25.7	17.1	36.2	55.4	26.7	9.9	20.9	31.9
		II	23.4	23.9	50.7	77.4	24.0	13.6	28.7	43.9
		III	22.2	37.8	80.0	122.2	21.2	21.1	44.6	68.2
	70	I	69.3	26.2	53.2	80.1	74.0	15.7	31.8	48.0
		II	63.5	33.7	68.2	102.7	66.1	19.9	40.4	60.8
		III	55.4	45.5	92.3	139.0	55.9	26.7	54.1	81.5
6 per cent..	50	I	34.0	45.6	95.1	144.7	34.5	26.3	54.9	83.5
		II	32.2	63.7	133.0	202.3	31.3	36.1	75.4	114.6
		III	33.6	100.6	210.0	319.5	29.1	56.1	117.2	178.3
	70	I	110.3	97.6	199.8	301.9	116.4	58.5	119.6	180.8
		II	101.3	125.2	256.3	387.3	102.9	74.1	151.7	229.3
		III	91.6	169.4	346.6	523.9	87.4	99.4	203.3	307.2

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(PROFESSIONAL PAPER.)

THE MIGRATORY HABIT OF HOUSEFLY LARVÆ AS INDICATING A FAVORABLE REMEDIAL MEASURE. AN ACCOUNT OF PROGRESS.

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INTRODUCTION.

In the proceedings of the third meeting of the General Malarial Committee held at Madras in November, 1912, there is given a summary of a paper on "Insect Psychology" by Prof. L. M. Howlett. From his experiments with fruit flies, the stable fly, and mosquitoes he comes to the conclusion that "we must regard insects not as intelligent beings consciously shaping a path through life, but as being in a sort of active hypnotic trance." Also, that "once we discover the stimuli or particular conditions which determine a mosquito's actions we hold the key to the position, since we can then apply our knowledge to the mosquito's undoing." The second statement might have been made as general and inclusive as the first. One often hears expressed a general proposition to the effect that the problem of the control of any insect is very largely a problem of its behavior. If its habits are known, some means of control are usually not far to seek. Thus in the warfare against the common housefly there are two important lines of attack based on a knowledge of the habits of the adults. In the first place, advantage is taken of their feeding and drinking habits in the use of such things as sour milk, formalin and milk, beer and sugar, the fly poisons, etc., as bait for traps or as poisons. Secondly, a knowledge of the egg-laying habits of the female leads to the use of covered fly-tight receptacles for manure, garbage, or other fermenting material. Both of these methods are based on a knowledge of the habits of the adults. The question now presents itself, Is there any phase of the behavior of the larvæ which may afford a line of attack? Do they have any characteristic habit of which advantage may be taken in attempts to destroy them?

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THE MIGRATORY HABIT

One need make only a few observations on the behavior of housefly larvæ to discover an excellent example of what Prof. Howlett calls "a sort of active hypnotic trance." This is to be found in the migratory habit which is so much in evidence during the prepupal stage. The habit has long been known and repeatedly mentioned in the literature. Thus Newstead (1907)[1] found that "deep down at the sides, in the cooler portions of the receptacles, the pupa or chrysalis stage occurred in enormous numbers, looking like small heaps or collections of reddish berries."

Griffith (1908) found that "the larvæ remained in the hottest part of the heap, but the pupæ were all found near the surface where it was cooler."

Jepson (1909), in certain rearing experiments in which moist bread was used as food, found that "the larvæ rarely left their feeding ground till fully fed, when they left the moist mass of bread for the surrounding dry area and there pupated."

Herms (1911) states that "the growing stage requires from four to six days, after which the maggots often crawl away from their breeding places, many of them burrowing into the loose ground just beneath the manure pile, or crawling under boards or stones or into dry manure collected under platforms or the like. * * * The larvæ often pass three or four days in the prepupal or migrated stage before actually pupating."

R. I. Smith (1911) says "it was very apparent that the maggots which swarmed through the manure were inclined to congregate in certain corners or crevices and pupate in a mass. * * * Scattered pupæ were discovered around the edges of the piles of cow manure and even in the soil underneath where the maggots had burrowed before pupating."

Hewitt (1912) states that "when full grown the mature larva usually leaves the moist situation in which it has developed for one of a drier nature, often crawling for several yards in search of some dry and sheltered crevice. Here it rests for a short time preparatory to changing into the pupal stage."

If any further evidence were needed to demonstrate such an habitual mode of action I might mention the following observations: During the past few months it has been my duty to assist in carrying out an extensive series of experiments in testing the value of various chemicals in treating manure with a view to the destruction of the larvæ present. The manure is placed in large cages and the chemical to be tested is sprinkled over it. The bottom of the cages consists of a galvanized iron pan with sides 1 foot high. In the floor of the pan are nine small holes. The sides of the cages above the

[1] Numbers in parentheses refer to dates in the bibliography, p. 11.

pan are of two layers of screen wire 2 inches apart. Now it was found in the very first experiments that larvæ were escaping from the cages, and it was seen that they found their way out through the holes in the floor of the cages and also through the screens at the sides. The numbers so escaping were surprising. It often happened that several hundred crawled out of the cage during 24 hours. They were found in the vessels placed beneath the cages to catch any drippings. By day the light was sufficient stimulus to prevent them from crawling out at the sides, but at night they were actually seen, with the aid of a flash light, making their way through both thicknesses of screen wire and dropping into the vessel below.

Moreover, in examining manure heaps on the open ground I have many records showing this "tendency to congregate" at the edges of the piles near the ground. About two cartloads of horse manure had been piled out on the open ground for five or six days during August, and at the end of this time it was hauled away. I examined the ground where the heap had been and found many pupæ, not in the center of the area formerly covered by the heap, but around the margin. Some were found on the surface, doubtless shaken out of the manure at the time of removal; others were found buried a half inch or more in the soil, where the larvæ had burrowed just previous to pupation.

In another case some 50 cubic feet of manure had been heaped up in a pile the base of which covered an area about 4 feet square. After the pile had stood three days larvæ were found swarming in the warm, moist parts of the heap near the top and some distance in from the sides. After eight days the entire pile was torn apart and gone over carefully in search of pupæ. None was to be found in the upper parts of the heap where I had previously seen great numbers of larvæ. In fact none was found until the very lowest layers were exposed. Here about 9,000 were collected. Not more than 100 were found below the soil. The mass of pupæ were scattered in little heaps about the margin. They were just outside the moist area of the manure, yet sufficiently protected from drying and sunlight by the overhanging straw. The explanation of their presence in such a position is, of course, that the larvæ, just before pupating, had migrated from the moist feeding grounds to a drier region more favorable to the resting stage. The examination of many other piles of manure showed the very same conditions existing, the only difference being in the number of pupæ collected.

Altogether some 50 or more heaps of manure on open ground have been examined. Each one contained from 40 to 50 cubic feet of manure. Some contained much long straw, others very little straw or bedding of any kind. The puparia are not hard to find nor hard to collect because of their occurrence in masses at the

edges of piles. Here are some of the figures obtained from a count of the pupæ collected from different piles: 7,000, 1,500, 10,000, over 12,000, 4,500, 6,000, 6,700, 30,000, etc.

In a recent article in the American Journal of Public Health, Levy and Tuck make the following statement: "We therefore announce the biological fact that the house fly does not pupate in manure if the full-grown larvæ can find any means of reaching and entering the earth." They claim that "the adult larvæ *regularly* leave the manure heap" and that they "enter the earth whenever it is possible for them to do so." To be sure, larvæ may and often do burrow into the ground before pupating—witness Dr. Terry's observations at Jacksonville, Fla., where he found larvæ and pupæ in the ground of soil-floor stables—but that they do so *regularly* is open to serious question. The figures given above are for puparia collected *above the surface* of the ground and *in the manure.* After the removal of the heaps, examination of the ground revealed only a very small percentage beneath the surface. The fact that some were found there shows that it was not the compact nature of the soil which prevented the majority from burrowing and that there was no reason why all could not have done so if such were their regular habit. It would seem that Levy and Tuck have put too much emphasis on this one point. A broader view, including all the phases of the migration of these creatures, is necessary and will not detract from the importance or value of the "maggot trap" which they have devised.

It is quite certain that the migrating habit is deeply ingrained and highly characteristic of housefly larvæ. A consideration of the known facts in the case will enable one to draw some inferences as to "the stimuli or particular conditions" which determine this mode of action. It has been noted that a sort of "wanderlust" seizes the larvæ just before pupation. It must be, therefore, that the migration is initiated in response to internal stimuli incident to the maturing of the larval stage and the onset of the metabolic changes preparatory to the transformation to the pupal stage. The course and direction of their travels are determined largely by external stimuli. It is quite evident that as pupation draws near they flee the very moist regions of a manure heap and seek the comparatively dry regions. If no such dry places are to be found in the manure, they will leave it to pupate in the ground or in cracks or crevices, under boards or stones, in loose material of any kind. Dr. Terry found both larvæ and pupæ in the soil of dirt-floor stalls. The larvæ were found in that part of the floor kept moist by the urine, while the pupæ were found in a ring in the drier soil outside the moist center. Further proof that moisture acts as a stimulus in determining their choice of a place for pupation is given below.

It is well known that they avoid light, and the rapidity with which they disappear from view when exposed to light through the disturbing of their feeding grounds is a familiar sight. The observation mentioned in which larvæ were seen crawling out through the screened sides of cages at night, but never during the day, is a case in point.

They avoid the extremely hot portions of manure heaps. Thermometers inserted from 6 to 12 inches toward the center of a heap will register anywhere from 110° F. to 170° F., which, of course, would be fatal. The hotter the pile the nearer the surface are the larvæ to be found. They also avoid the moldy parts of the heap. They seek, as it were, the safety of the middle region between the heat and mold of the center and the exposure to sunlight and dryness of the exterior. Doubtless other conditions also have an influence in determining their actions.

The habit of seeking the comparatively dry regions near the edge of manure heaps at the time of pupation is an adaptation of great advantage in that the adult fly at the time of emergence is thus afforded an easy path to freedom. It prevents the drowning of the imagines and insures the quickest possible expansion and drying of the wings. At least this is the teleological explanation. Yet it can not be claimed that these are intelligent acts, nor that the future is consciously provided for. We have here indeed a "battalion of somnambulists" acting in blind response to various internal and external stimuli.

THE BEARING OF THE MIGRATORY HABIT ON THE PROBLEM OF CONTROL.

So far as I have been able to determine, Levy and Tuck were the first to take advantage of the migratory habit in an attempt to destroy the maggots. In their paper published in July, 1913, they report two experiments. In the first they placed manure in a barrel in the bottom of which several holes had been bored, with the result that on the following day thousands of maggots were found in the tub placed beneath, and the number seemed to increase for three days. In a second experiment the bottom of the barrel was replaced by stout wire gauze. The results of this trial are not given.

It was not until the beginning of November that I learned of their work, and it was near the end of the month before I had an opportunity of reading the article. I had already carried out two experiments during the summer at Arlington, Va., and others during the fall at Audubon Park, New Orleans, La. The possibility of taking advantage of the migrating habit was suggested to me by experience with larvæ escaping from cages used in other experiments. The results of the experiments were beyond my best expectations, and

in the hope that they may be of some interest to others they are here reported in some detail.

A large galvanized iron pan, measuring 5 by 3 feet, with sides 4 inches high, was made. In this stood a container on legs 8 inches high. This container measured 4 by 2 by 2 feet. The sides and bottom were of heavy wire, ¼-inch mesh, supported by a light wooden framework. Twelve cubic feet of manure well infested with eggs and larvæ were placed in this container and sprinkled with water. Water was also poured into the pan below to the depth of about 1 inch. Surrounding and covering both pan and container was a fly-tight inclosure made of a large cage, 6 by 6 by 6 feet. This prevented further infestation of the manure, and an arrangement of traps at the top of the cage made it possible to capture and keep a record of any flies that might emerge. At the time for the emergence of flies the sides of the cage were darkened with black cloth in order to drive the flies into the traps at the top. Each day the larvæ were collected from the pan and counted, and each day the manure in the container was sprinkled thoroughly with water and the pan was washed out and again partly filled with water to drown the larvæ which fell into it. The records of Experiment No. 1 are summed up briefly in Table I.

TABLE I.—*Migratory habit of housefly larvæ; Experiment No. 1.*

Date.	Larvæ collected from pan.	Flies from traps.	Date.	Larvæ collected from pan.	Flies from traps.
1913			1913		
Aug. 27	337	.....	Sept. 6	0	88
28	715	.....	7	.....	102
29	1,550	.....	8	.....	23
30	[1] 10,000	.....	9	.....	19
31	[1] 8,000	.....	10	.....	9
Sept. 1	2,160	.....	12	.....	5
2	670	3	15	.....	6
3	263	18			
4	([2])	8		23,999	303
5	304	22			

[1] Approximate.

[2] Collected on following day.

A few flies at the time of emergence fell into the water of the pan and were drowned. Allowing for these and for the few which may have escaped from the cage during the opening and shutting of the door, the total number of flies may be placed at 350. It will be seen from these figures that out of a possible total of 24,350 24,000, or a little more than 98 per cent, were destroyed through the catching of the larvæ in the manner described.

A second experiment was started on September 16. The manure used was from the same source as in the first experiment and contained practically the same proportion of straw. The same amount was used, viz, 12 cubic feet. The only respect in which this experi-

ment differed from the first was in the fact that the manure in the container was not sprinkled with water at any time, except for a light shower on September 19 and another on September 22. Much of this rainfall failed to reach the manure in the container because of the covering of the cage. A comparison of the results of this experiment with those of the first indicate the importance of moisture as a stimulus.

TABLE II.—*Migratory habit of housefly larvæ; Experiment No. 2.*

Date.	Larvæ collected from pan.	Flies caught in traps.	Date.	Larvæ collected from pan.	Flies caught in traps.
1913			1913		
Sept. 17	15	.....	Sept. 30	.....	64
18	132	.....	Oct. 1	.....	80
19	168	.....	2	.....	125
21	894	.....	3	.....	52
22	427	.....	4	.....	78
23	35	.....	6	.....	84
24	0	.....	7	.....	44
27	.....	43	8	.....	22
28	.....	43			
29	.....	33		1,671	668

Allowing for the few larvæ and adults which may have escaped, the totals may be given in round numbers as 1,700 larvæ and 700 adults. Thus from a possible total of 2,400, 1,700, or about 71 per cent, were destroyed. In passing it is unnecessary to point out that here 700 flies *did* pupate in the manure in spite of the fact that they had every opportunity to leave it.

With the approach of cold weather the work against the housefly was transferred to the experiment station at Audubon Park, New Orleans, La. Some other experiments of a similar nature were carried out here with smaller containers and cages. The strong wire baskets of the kind commonly seen in markets and stores for the display of fruits and vegetables made first-rate "maggot traps." The baskets used were 16 inches in diameter and 16 inches high and stood on legs 9 inches high. A galvanized-iron pan 2 feet square was made for this to stand in, and over all this was placed a cage consisting of a light wooden framework covered with black cloth. The top of the cage was covered by boards in which was an opening for the attachment of flytraps.

The third experiment was started on November 13. The basket was filled with manure taken from stables on November 12. The manure, which contained very little straw or bedding of any kind, was packed firmly in the basket and sprinkled with 4 quarts of water. The iron pan below was partly filled with water. The cage with its traps was not put in place until November 18, thus exposing the manure to possible infestation for a period of five days. The manure was sprinkled daily as long as larvæ appeared.

TABLE III.—*Migratory habit of housefly larvæ; experiment No. 3.*

Date.	Larvæ collected from pan.	Flies caught in traps.	Date.	Larvæ collected from pan.	Flies caught in traps.
1913.			1913.		
Nov. 14	162	.....	Nov. 27	.....	3
15	656	.....	28	.....	2
16	1,950	.....	29	.....	2
17	2,650	.....	Dec. 1	.....	2
18	1,240	.....	2	.....	8
19	40	.....	3	.....	5
20	[1]	7	4	.....	6
21	12	0	5	.....	15
22	0	0	6	.....	10
23	0	0	7	.....	3
24	0	0			
25	0	4		6,710	69
26	.....	2			

[1] Collected on following date.

Out of a possible total of 6,779 there were destroyed 6,710 larvæ, that is to say, about *99 per cent* were destroyed before they reached the pupal stage.

The percentages obtained in these experiments clearly demonstrate the habitual nature of the migration. They also demonstrate the efficiency of the maggot trap which is designed to take advantage of this mode of action. The question immediately arises whether the trap which appears so successful in an experimental way on a small scale can be adapted to the handling of manure in a practical way and on a large scale. Every consideration points to the probability that it can and that it will afford "an additional weapon of great value." However, the final verdict as to the value of the maggot trap must wait upon the solution of certain practical problems. To point out some of these here is to suggest lines for further investigation.

(1) In the first place, there must be determined what form, size, and construction of trap will give the best results. The answer to this will depend largely on the particular conditions obtaining at any given stable, such as the amount of manure produced daily, the arrangements for drainage, etc. It will also depend on the answer to the following problems:

(2) How deeply may manure be heaped in a trap without interfering with the migration? It will probably be found that the depth will make little difference, provided that the manure is kept moist, and provided that avenues of escape are afforded at the sides as well as at the bottom. The importance of providing a way of escape at the sides was not taken into consideration by Levy and Tuck in their preliminary experiments.

(3) How long must manure be kept in a maggot trap before it is entirely free from larvæ? This is a very important question from a practical standpoint, and one will find scant suggestion as to the answer in the literature on the life history and habits. The housefly

breeds preferably in horse manure, but it has never been determined just how long a given lot of manure continues to be an attractive place for egg laying, nor for how long a period fly larvæ will continue to appear in it. It is obvious that the maggot trap would not be practical if the infestation of the manure were daily renewed for a long time. Under ordinary conditions the drying of the surface of a heap of manure probably limits the period of egg laying to the first day or two of exposure. But in a maggot trap the manure must be kept wet in order to insure the greatest amount of migration. Would not such a moist surface be daily reinfested and maggots continue to appear in the manure as long as any fermentation were in progress? As a matter of fact, the period of infestation appears to be rather short, and even under the most favorable conditions maggots will rarely be found in a given lot of manure after 10 or 12 days' exposure. In support of this claim some experimental data may be given here.

A fourth experiment was carried out in the same manner as experiment No. 3, except that no cage was used to cover the trap at any time. The manure in the basket was thus continuously exposed to flies and the surface was kept moist by daily sprinkling. The larvæ were removed from the pan each day and counted and the pan was again partly filled with water. The manure used was taken from stables on November 12 and the experiment started on the same date. Larvæ began to appear in the pan on November 13 and continued daily to the 24th, as shown in Table IV.

TABLE IV.—*Migratory habit of housefly larvæ; Experiment No. 4.*

Date.	Larvæ caught.	Date.	Larvæ caught.
Nov. 13	14	Nov. 20	1,040
14	2,230	21	560
15	[1] 6,000	22	465
17	[1] 5,000	23	140
18	2,530	24	36
19	2,070		

[1] Approximate.

The manure contained little straw or other bedding and was very attractive to the flies as evidenced by the heavy infestation (about 20,000 from a little more than a bushel of manure). Yet no larvæ were to be found in the manure after 12 days.

Examination of heaps of manure on open ground has shown in many cases that at the end of eight days only pupæ were to be found in the manure. Even in cases where the manure was especially attractive to the flies, by reason of active fermentation and the absence of straw, all were found to have reached the pupal stage by the tenth day. Any device for applying the principle of the maggot trap on a large scale must take this time factor into consideration.

(4) The disposal of the maggots is another practical consideration. If the larvæ were allowed to drop to the ground they would burrow into it to pupate there and nothing would be gained. It would be necessary to have some sort of vessel, e. g., a concrete basin, beneath the trap. This should have vertical sides and contain an inch or more of a weak disinfectant or of water covered with a film of oil. If such a basin were connected with a sewer or cesspool the maggots collecting in it could be flushed out each week without the necessity of handling them in any way and without any offensive decomposition.

That the maggot trap possesses certain advantages is obvious and ought to lead to many attempts to develop it along practical lines. Cheapness would be one of its strong points. Practically the only cost would be the initial one for the construction of the trap and of a basin or receptacle for catching and disposing of the maggots. Very little additional time or labor would be required in operating it. The sprinkling of the manure would be a very small part of the daily routine of removing the manure from the stables. Proper arrangements for the disposal of the maggots would require only a few minutes' attention at long intervals.

Incidentally it may be noted that the maggot trap offers a convenient and easy means to the investigator or teacher who wishes to collect coprophagous larvæ in large numbers. In the experiments just reported the larvæ of *Musca domestica* L. were the most numerous, but in addition there were also collected larvæ of *Stomoxys calcitrans* L., of Homalomyia, of certain Sarcophagidæ, and doubtless of others. The total numbers collected were so large that no attempt was made to determine the relative abundance of the various forms.

SUMMARY.

Observations and experiments show that the migratory habit is deeply ingrained and highly characteristic of housefly larvæ.

The migratory habit appears in the prepupal stage in response to various internal and external stimuli.

Of the external stimuli, moisture is perhaps the most important in determining the direction of their travels and the choice of a place for pupation.

The migratory habit is an adaptation of great advantage in that it insures to the issuing adult the easiest and quickest escape.

This deep-seated habit offers an important point of attack in the attempts to control the pest.

Experiments with maggot traps show that 98 or 99 per cent of the total number of larvæ can be made to leave the manure, provided it is kept moist. Even from comparatively dry manure as many as 70 per cent can be destroyed.

The development of the maggot trap into an efficient weapon in the warfare against the housefly involves the working out of certain practical points, viz, the size and structure of the trap, the time necessary to keep the manure in the trap to rid it of maggots, the disposal of the larvæ, etc.

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No. 15

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

October 16, 1913.

A SEALED PAPER CARTON TO PROTECT CEREALS FROM INSECT ATTACK.

By William B. Parker, *Entomological Assistant.*

ECONOMIC IMPORTANCE OF THE PROBLEM.

During an investigation of the insects attacking dried fruits at Sacramento, Cal., during 1912, the infested condition of packed cereals was brought to the writer's attention. The economic importance of these infestations is greater than at first appears. The purchaser usually returns infested packages to the grocer. The grocer returns them to the mill where they were prepared. The mill screens the cereal and sells it as feed. Thus the condition of the cereal itself is the cause of a disagreeable feeling on the part of the consumer and occasions a loss of time to the grocer and a considerable loss financially to the miller.

Besides this intrinsic loss, the consumer may demand of the grocer another "brand" in the hope of finding a cereal which is not infested by insects, or, by jumping to the sudden conclusion that all cereals are infested during the summer, may forego the use of breakfast foods for a time. The exact financial loss due to these conditions can not be accurately determined, but extensive observations lead to the belief that it is much greater than most millers suppose.

PRELIMINARY OBSERVATIONS.

Examinations of infested packages taken in grocery stores, warehouses, and mills showed that the majority of infestations commenced at the ends of these packages, or where a small hole had been broken in the edge, due to rough handling. The cereal in these packages was sterilized prior to being packed, so that the insects which caused the infestation must have deposited their eggs after, or shortly before, the cereal was packed. The presence of the confused flour beetle (*Tribolium confusum* Duv.) inside of the ends and the presence

of small openings at the corners of many packages led to the conclusion that if cereals were run directly from the sterilizer into cartons, which in turn were properly sealed, infestation would not in most cases take place. This theory was strengthened by statements from grocers to the effect that certain packages which were carefully sealed were not returned to them because of the presence of insects.

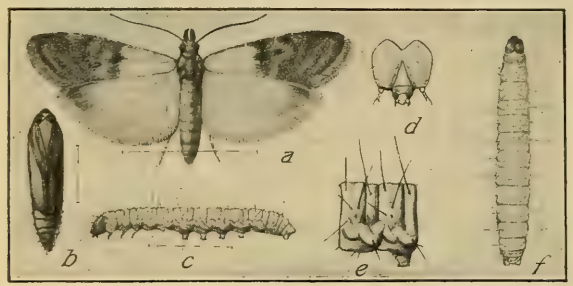

FIG. 1.—The Indian-meal moth (*Plodia interpunctella*): *a*, Moth; *b*, pupa; *c*, larva; *f*, same, dorsal view; *d*, head, and *e*, first abdominal segment of larva. *f*, Somewhat enlarged; *d*, *e*, more enlarged. (After Chittenden.)

INSECTS CONCERNED.

There are several insects which attack stored cereal products. Among the more important are the Indian-meal moth (*Plodia interpunctella* Hübn.) (fig. 1), the Mediterranean flour moth (*Ephestia kuehniella* Zell.) (fig. 2), the meal snout-moth (*Pyralis farinalis* L.), the saw-toothed grain beetle (*Silvanus surinamensis* L.), the confused flour beetle (*Tribolium confusum* Duv.) (fig. 3), the granary weevil (*Calandra granaria* L.), and the rice weevil (*Calandra oryza* L.). These are the principal insects which are likely to infest packed cereals.

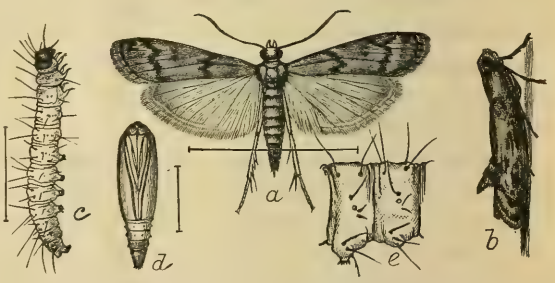

FIG. 2.—The Mediterranean flour moth (*Ephestia kuehniella*): *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa; *e*, abdominal segments of larva. *a–d*, Enlarged; *e*, more enlarged. (After Chittenden.)

There is an erroneous opinion with some people that the cereals become infested by spontaneous generation. This, however, is impossible; and when any insects are found in packages it is because the eggs, larvæ, or adults have gained access to the cereal after it has been sterilized.

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Using the foregoing observations as a basis, the following experiments were conducted, the idea being to test the efficiency of a cheap sealed carton.

A cereal was sterilized to such an extent that when it was placed in a package the temperature developed was 180° F. The packages themselves were sterilized before being filled, but had there been any

insects or eggs in them the heat from the cereal would undoubtedly have killed them.

When the ends of the packages were being fastened, the glue was not placed near the corners, so that if it were possible to leave an opening there by accident, the opening would be left in this experiment. All of the packages were regularly closed by gluing the ends, but some of them were covered by a piece of label paper (fig. 7) so that there were no openings where an insect could enter without piercing the label. Some of the labels were put on with glue and some with flour paste.

Eighteen of these packages, nine labeled and nine not labeled, were distributed in two wooden boxes. Between them flour and meal that

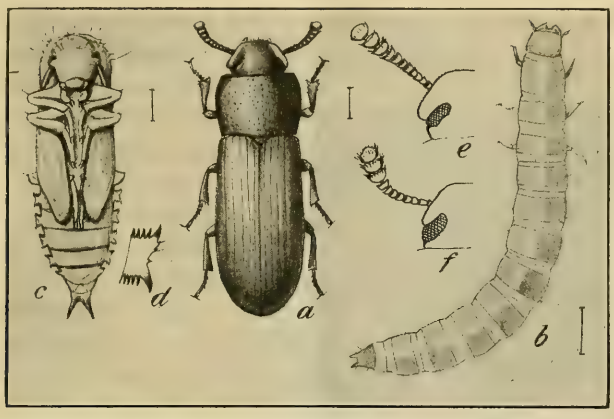

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TABLE I.—*Recorded conditions of infestation or noninfestation found in packages of cereal opened Nov. 10, 1912.*

No. of package.	Not labeled.	Label pasted.	Label glued.
1	Infested, containing web and adults		
2	do		
3	do		
4	do		
5		No infestation	
6		do	
7			No infestation.
8			Do.

A similar observation was made on January 24, 1913, the results of which are shown in Table II.

TABLE II.—*Conditions of infestation or noninfestation of 10 packages of cereal left until Jan. 24, 1913.*

No. of package.	Not labeled.	Label pasted.	Label glued.
9	Infested, containing web and adults		
10	do		
11	do		
12	do		
13	do		
14		No infestation	
15		do	
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The results of this experiment seem very conclusive. Figure 4 shows the relative infestation on the outside and inside of the labeled and nonlabeled packages. These packages were all placed under the same conditions and given every chance to become infested.

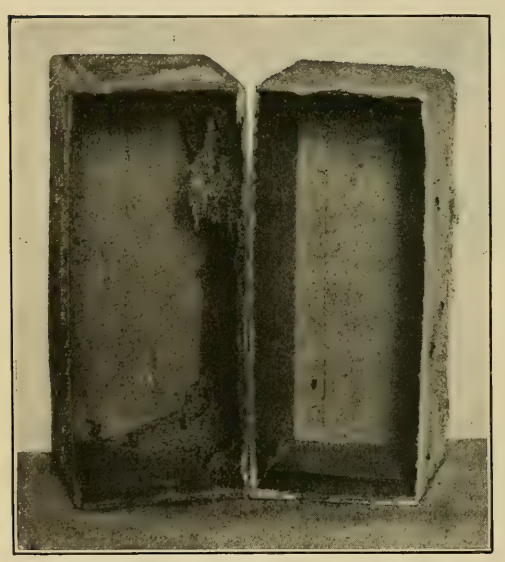

FIG. 4.—Results of experiments with cartons. The one on the left shows severe infestation; the one on the right had a thin label pasted on the outside and is not infested. The webs and adults of the infesting insects are shown on the outside of both cartons. (Original.)

The thorough infestation of nonlabeled packages and the absence of infestation in the labeled packages clearly indicate the efficiency of the label in preventing the insects from entering the cartons.

These experiments do not prove that insects are incapable of boring into the carton, thus infesting the cereal, but they do prove that when placed in regions of severe infestation the ordinary paper carton will become infested while the sealed carton will not.

WHERE INFESTATION TAKES PLACE.

In the process of sterilization the cereal is heated to a sufficiently high temperature to cause the death of all insect life, but following this process there are several ways in which it may become infested.

While on an elevator (see fig. 5) the cereal may be infested by eggs, larvæ, or adults of the several insects dropping or crawling into it. Warehouses are usually more or less infested by insects which crawl around on the packages. The grocer's storeroom and shelves are also

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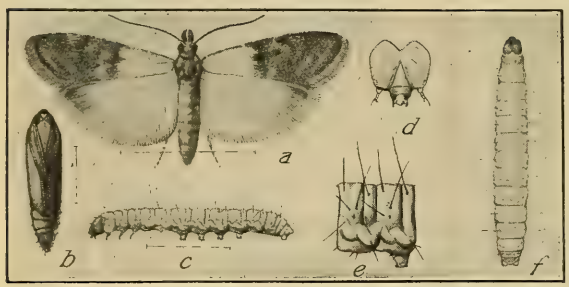

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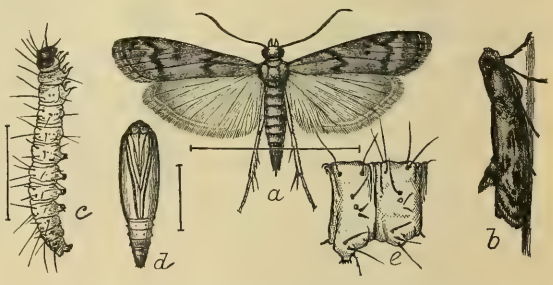

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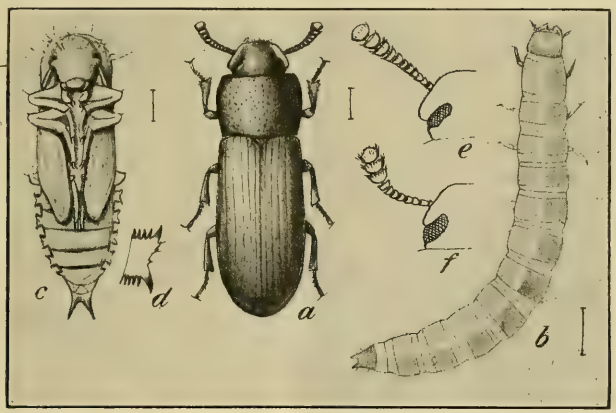

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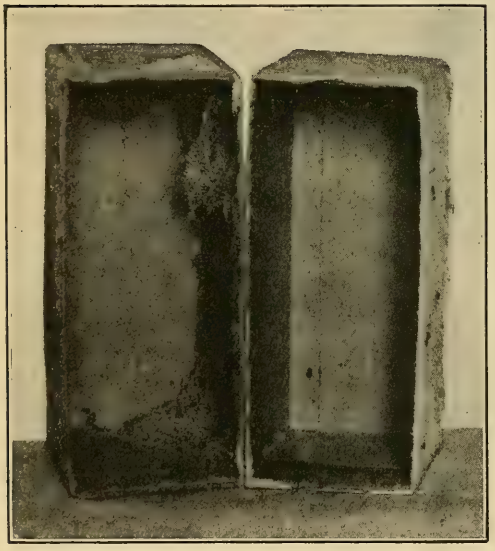

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places where infestation takes place. Unless put into insect-proof carton the cereal, therefore, is subject to infestation from the

FIG. 5.—Cereal elevator which leads from sterilizer to packing room. Infestation may easily take place here. (Original.)

time it comes from the rolls or the sterilizer until it is sold to the consumer. Infestation may, of course, take place after the package

is opened by the purchaser, but this does not concern the manufacturer.

DRYING THE CEREAL.

After the cereal has been sterilized it may contain too much moisture to be packed, and a drying process then becomes necessary. In the case of cereals which are not flaky and to which agitation is not injurious, a sterile chute with baffles (fig. 6), through which hot,

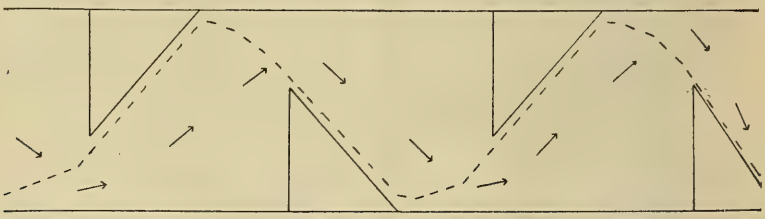

FIG. 6.—Diagram of chute with baffles for cooling cereal. (Original.)

dry air is blown, would be effective. The air is thus placed in contact with the falling cereal. In the case of flaky cereals a belt elevator is necessary, but this can be inclosed and the hot air used as in the former case. Both elevators should be so constructed that they can be readily sterilized with air at a temperature above 180° F. This should be occasionally done as precaution against infestation.

THE SEALED CARTON.

The sealed carton may be made of a stiff, though perhaps a cheaper, grade of cardboard than is used when the cardboard itself is printed. The printed label should be made in three pieces, namely, two ends, which lap over the edges and extend a short distance down the side; and a side piece, which securely covers the edges of the end pieces. (See fig. 7.) One sealed carton was observed which had a strip of paper pasted across the corners before the ends were put on. This further insures the resistance of the carton to insect attack and is advisable, provided the cost is not too great.

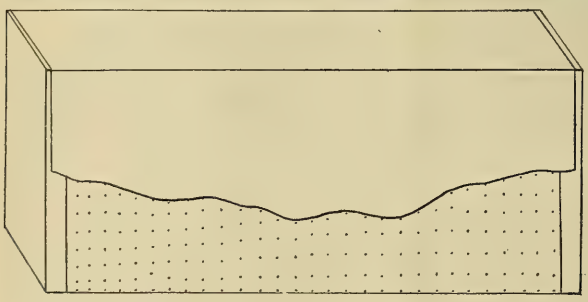

FIG. 7.—Diagram of carton, showing method of applying label to protect inclosed cereal from insect attack. (Original.)

A sealed package was observed on which the ends of the carton were not as firmly glued as they would have been had the package

not been labeled. The looseness of this end caused a break in the label, which, of course, ruined the seal of the package. Care in the proper sealing of the ends of the carton before applying the label will remedy this defect.

The extra cost of a sealed package over the ordinary one will vary with the labor or machinery available and the cost of materials. It has been estimated at 1 cent for a 2-pound package, but it is best determined by each miller for his particular locality. With right management the cost should not prove excessive, while the use of the well-made sealed package will minimize the chance of infestation. The improved appearance of such a package, also, renders it more attractive to the prospective buyer.

PACKAGES OTHER THAN SEALED CARTONS.

Other forms of packages have been suggested, the most promising one being a sealed paper bag placed inside of an ordinary carton.

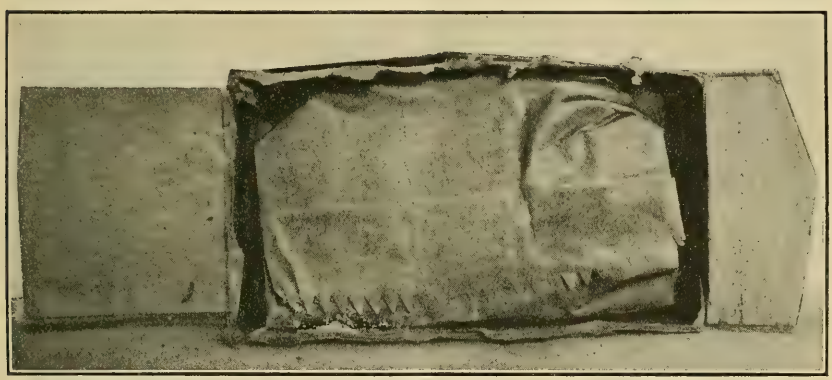

FIG. 8.—Carton with paper bag inside. Note larva on cover, and loose cereal which it has webbed together. (Original.)

Although this forms a barrier to insects which have crawled through the openings in the corners of the carton, it places them with little or no food firmly against a thin wall of paper through which they would be very likely to force their way.

Furthermore, it was observed that the ends of the paper bags were not readily sealed; small openings were left in many cases. One firm using this package reported that about as many of this type were returned infested as of the old-style packages.

Again, the small amount of cereal spilled between the bag and the carton is used by a larva, as shown in figure 8, and, in any event, the presence of insects on the top of the bag would be sufficient cause for the return of the package.

SUMMARY.

The foregoing observations and experiments have brought out several points:

(1) Cereals may become infested before they are packed, after the packages are placed in warehouses, and in the grocery stores.

(2) Insects find their way in at the small holes which are usually present at the corners of unsealed packages or at holes accidentally punched in the sides.

(3) Thorough sterilization[1] at 180° F. kills all insect life; and if the cereal is run from the sterilizer either through a sterile cooler or directly into sterile packages and immediately sealed, it will not become infested unless the package is broken.

(4) Sterilization of the knocked-down cartons before packing and cleanliness with regard to the exclusion of insects from the packing room will greatly facilitate the preparation of sterile packages and is strongly recommended.

(5) It is absolutely necessary that all machinery connecting the sterilizer and the packages be free from insects. If the cereal is passed through chutes or conveyors which can not be sterilized or are not kept sterile, it will, through these sources, become infested even though the cereal was previously sterile and was packed in sterile packages.

[1] The writer has not extensively investigated sterilizers, but the following description, furnished through the kindness of Mr. Bert D. Ingles, of a sterilizer used by a large flour mill in California may be of interest here. "In this sterilizer the screw conveyor is 6 inches in diameter and handles approximately 500 pounds of cereal per hour. The steam is held at 160 pounds pressure, which is equal to 370.5° F. A machine 8 feet long will heat the cereal under these conditions to 180° F. in two minutes without any difficulty. Such a sterilization does not injure the cereal."

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places where infestation takes place. Unless put into insect-proof carton the cereal, therefore, is subject to infestation from the

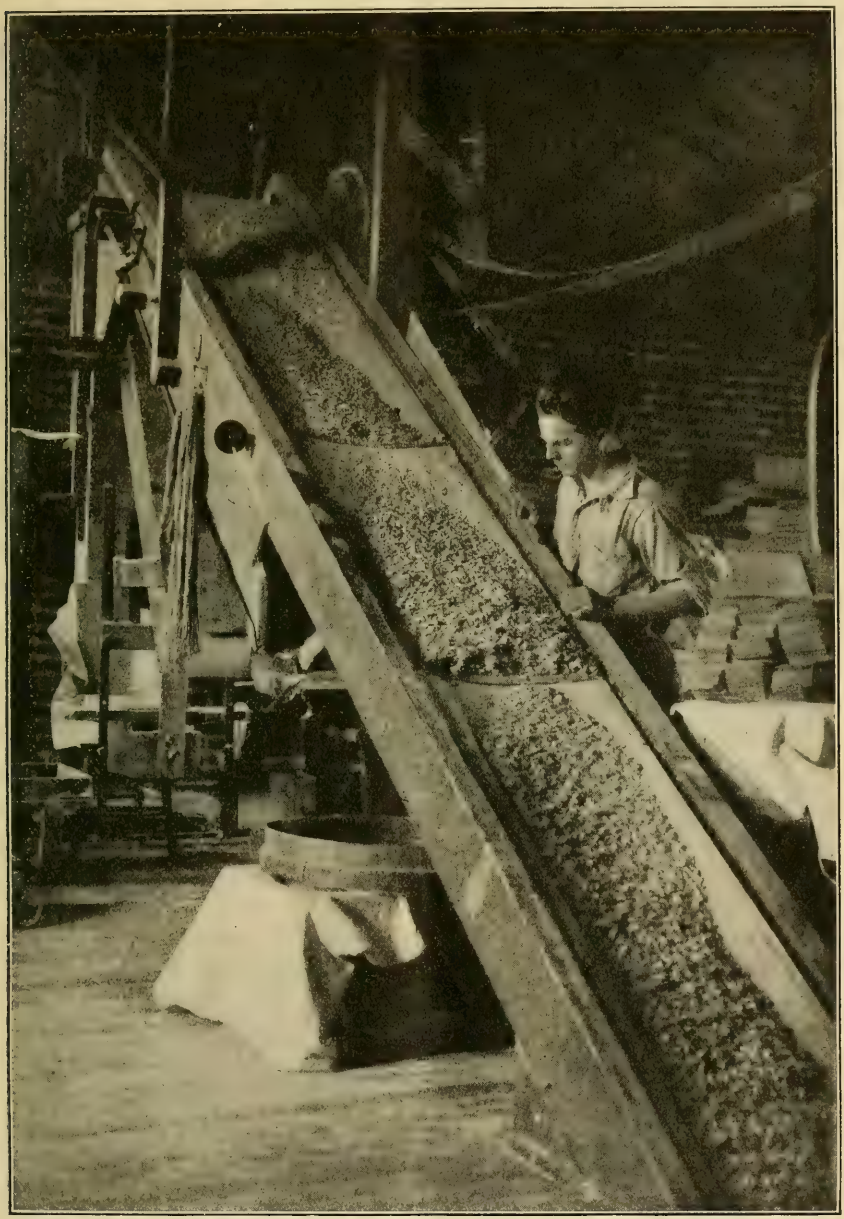


FIG. 5.—Cereal elevator which leads from sterilizer to packing room. Infestation may easily take place here. (Original.)

time it comes from the rolls or the sterilizer until it is sold to the consumer. Infestation may, of course, take place after the package

is opened by the purchaser, but this does not concern the manufacturer.

DRYING THE CEREAL.

After the cereal has been sterilized it may contain too much moisture to be packed, and a drying process then becomes necessary. In the case of cereals which are not flaky and to which agitation is not injurious, a sterile chute with baffles (fig. 6), through which hot,

FIG. 6.—Diagram of chute with baffles for cooling cereal. (Original.)

dry air is blown, would be effective. The air is thus placed in contact with the falling cereal. In the case of flaky cereals a belt elevator is necessary, but this can be inclosed and the hot air used as in the former case. Both elevators should be so constructed that they can be readily sterilized with air at a temperature above 180° F. This should be occasionally done as precaution against infestation.

THE SEALED CARTON.

The sealed carton may be made of a stiff, though perhaps a cheaper, grade of cardboard than is used when the cardboard itself is printed. The printed label should be made in three pieces, namely, two ends, which lap over the edges and extend a short distance down the side; and a side piece, which securely covers the edges of the end pieces. (See fig. 7.) One sealed carton was observed which had a strip of paper pasted across the corners before the ends were put on. This further insures the resistance of the carton to insect attack and is advisable, provided the cost is not too great.

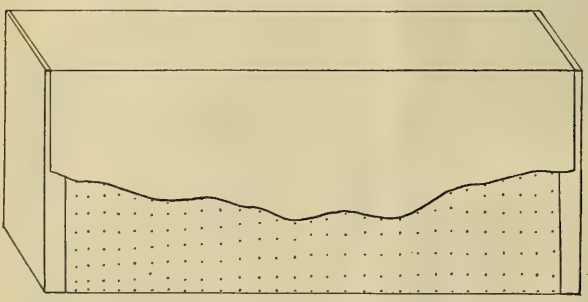


FIG. 7.—Diagram of carton, showing method of applying label to protect inclosed cereal from insect attack. (Original.)

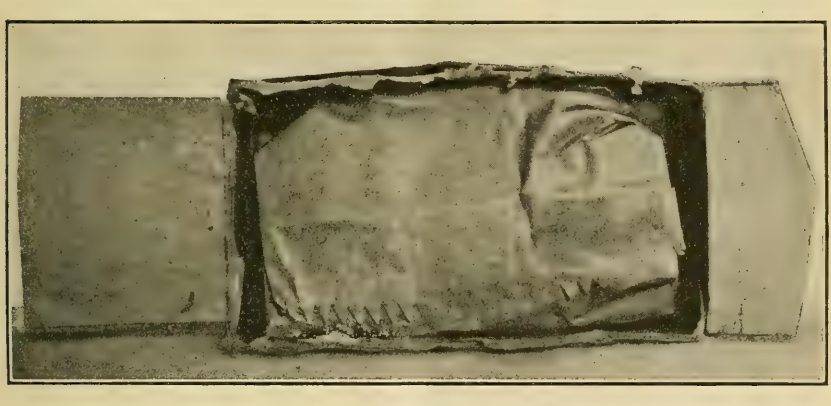
A sealed package was observed on which the ends of the carton were not as firmly glued as they would have been had the package

not been labeled. The looseness of this end caused a break in the label, which, of course, ruined the seal of the package. Care in the proper sealing of the ends of the carton before applying the label will remedy this defect.

The extra cost of a sealed package over the ordinary one will vary with the labor or machinery available and the cost of materials. It has been estimated at 1 cent for a 2-pound package, but it is best determined by each miller for his particular locality. With right management the cost should not prove excessive, while the use of the well-made sealed package will minimize the chance of infestation. The improved appearance of such a package, also, renders it more attractive to the prospective buyer.

PACKAGES OTHER THAN SEALED CARTONS.

Other forms of packages have been suggested, the most promising one being a sealed paper bag placed inside of an ordinary carton.



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No. 16

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
October 22, 1913.

THE CULTURE OF FLUE-CURED TOBACCO.

By E. H. Mathewson,
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INTRODUCTION.

In its origin the flue-cured type of tobacco is associated closely with the old Virginia dark type and is really an offshoot from the latter, dependent primarily upon soil modification. Later the type was further modified and differentiated by cultural adaptations prompted by trade preferences. As the cultivation of tobacco in Virginia was pushed back to the lighter sandy lands of what is now the southern tier of counties of that State and the adjoining counties of North Carolina, the character of the tobacco produced was naturally somewhat changed. It was milder and generally lighter in color and became popular for home consumption, particularly as a chewing tobacco. It was preferred also by a certain class of the export trade, particularly in France, where the milder, lighter tobaccos were more popular. The dark Virginia tobacco was cured by means of open fires and smoke, which gave it a smoky, creosotic odor and flavor. This smoky flavor was objectionable to the trade desiring the milder tobacco, and the use of open fires in curing was limited as much as possible, and much of the product was merely air cured, fires being used only when necessary to protect it from damage in damp, muggy weather. Charcoal was often substituted for wood in order to keep down the odor of smoke. The use of charcoal grew to be the regular practice until, in turn, it was superseded by the use of flues, which came into use soon after the close of the Civil War. At first these flues were constructed of rock, but later they were made of sheet iron, as is the almost universal practice to-day. The use of flues still further did away with any tendency to smokiness and gave more uniformly satisfactory results in obtaining lighter and more uniform colors, as well as greater convenience in tending the fires.

Up to a time just before the Civil War, however, the production of this yellow type of tobacco was confined principally to Caswell County, N. C., and Pittsylvania County, Va. The real development in the flue-cured type did not take place until during the decades immediately succeeding that in which the Civil War occurred, and on its present basis, therefore, it is essentially a modern type.

A number of important and clearly defined factors are easily discernible as stimulating and promoting this development. From the standpoint of consumption, the demand was rapidly expanded by the growing popularity of pipe smoking in this country, for which this flue-cured type, in the form of granulated smoking tobacco, proved to be highly satisfactory, and also to the introduction and rapid expansion in use of machine-made cigarettes. The greatly enhanced demand for tobacco of this type also extended to foreign countries, especially to Great Britain and certain of the British possessions. Supplementary to this great expansion in demand, resulting in good prices for the raw leaf, production was also markedly stimulated during this same period by the introduction of commercial fertilizers, upon which the profitable production of flue-cured tobacco now so largely depends. By the middle eighties, therefore, the producing area and use of flue-cured tobacco had greatly enlarged and covered, as a crop of dominant importance, some 20 counties in the northern part of central and western North Carolina and in south central Virginia, thus embracing the Old Belt section about as it is known to-day. Prior to about 1890 little tobacco was grown east of Warren, Franklin, and Wake Counties, N. C. During the nineties the demand for flue-cured tobacco, especially of the brighter types, continued to expand, and in this same period the price of cotton was very low. This combination of circumstances resulted in a widely extended movement on the part of the farmers of eastern North Carolina and South Carolina to try tobacco growing where formerly attention had been given almost exclusively to cotton. So rapidly was the acreage expanded throughout this cotton-growing Coastal Plain section of eastern North Carolina and South Carolina, now known as the New Belt, that in 1903 this new section actually produced more tobacco than was grown in the Old Belt section. Because of this large production in the New Belt, the total crop of flue-cured tobacco of that year for both the New Belt and the Old Belt amounted to upward of 250,000,000 pounds, the largest crop produced up to the present time. This great crop year ushered in a period of lower prices, and production dropped off markedly in succeeding years, particularly in the New Belt, where attention was again turned to cotton, for which prices for several years were comparatively good. In 1911 and 1912 the flue-cured tobacco crop was considerably curtailed because of very

unfavorable weather conditions, and prices for the brighter types of leaf again became very high, foreshadowing a greatly increased interest and expansion of acreage, more especially in the New Belt section, where the acreage and production fluctuate much more widely than in the Old Belt because of the opportunity for shifting between cotton and tobacco as conditions seem to warrant.

At the present time, the normal annual production of flue-cured tobacco on a farm-weight basis is estimated to be about 215,000,000 pounds. Of this total about 120,000,000 pounds is produced in the Old Belt section and 95,000,000 pounds in the New Belt.[1] The average annual production of tobacco in the United States is now close to 1,000,000,000 pounds, of which the flue-cured type is approximately one-fifth. White Burley is the only other type that has had such a rapid expansion in production and popularity in so limited a period of years. As in the case of Burley, the rapid development of flue-cured tobacco is undoubtedly founded largely on its adaptability for meeting the popular demand for light, mild tobacco in the different forms in which it is consumed.

All things considered, this flue-cured type of tobacco is unsurpassed in universal popularity and general adaptability to a variety of uses, including granulated and cut smoking tobacco, both paper and all-tobacco cigarettes, and plug filler and wrapper; in fact, it is adapted to all the regular forms in which tobacco is used except standard cigars and snuff. In color and general appearance it is very attractive, while its low nicotine content, mildness, aromatic sweetness, fragrance, and good keeping qualities render it very satisfying to the user.[2]

It may also be noted that this type is the only one that has had any decided tendency to expand our exports in recent years. Of the total quantity of flue-cured tobacco produced, about 40 per cent, or around 90,000,000 pounds, is exported, and the remainder is used in domestic consumption.

SOILS OF THE FLUE-CURED DISTRICT.

Speaking broadly, the current trade differentiations of the flue-cured producing area into the Old Belt and the New Belt sections indicate also a fairly well-defined modification in the character of the tobacco produced in these two sections. The best tobacco soils of both the Old Belt and the New Belt are all light and sandy, but those of the New Belt, in the Coastal Plain, are lighter and more sandy as a class than are those of the Old Belt in the Piedmont section, and these soils, and especially the subsoils, become progressively

[1] For additional information concerning the general features of the flue-cured type, including a list of the counties producing flue-cured tobacco, with the estimated average quantity of tobacco produced in each, see Bulletin 244, Bureau of Plant Industry, U. S. Department of Agriculture.

[2] U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 244, p. 70, 1912.

more clayey as one progresses westward toward the mountains. The lighter Coastal Plain soils characteristically produce a brighter and paler type of leaf than the Old Belt soils, but with less body and richness. In the western part of the Old Belt, particularly from about Rockingham County, N. C., and Henry County, Va., the rich waxy filler types predominate, while the colors run in much larger proportion to mahogany or red. Soil adaptation is a very important factor in the production of a satisfactory quality of flue-cured tobacco. It is an influence of fundamental importance in determining the color of the leaf produced, as well as such other points of quality as fineness, richness, and body. In general, the soils adapted to the production of flue-cured tobacco may be described as light and sandy to a depth of 6 to 10 inches, underlain with a sandy-clay subsoil of a yellowish orange color.

The whiter soils produce the brightest tobacco, unless offset by some other factor. The clay of the subsoil is an important factor in giving the leaf richness and body, and it is also an aid in retaining fertility. In the Coastal Plain section some of the soils are such loose, deep sands as to constitute an extreme of the bright-tobacco type. Such soils will naturally produce a very bright tobacco, but the leaf is likely to be lacking in body and richness, and the soil itself is at a disadvantage in retaining fertility and is not likely to withstand wet weather well. On the other hand, the soils of the Old Belt section, more especially in the western part, frequently represent the other extreme of being too clayey and too red to produce anything more than a dark tobacco, although, generally, the leaf will be rich and waxy. Between these soil extremes of the New Belt Coastal Plain section, some of them tending to be too extremely sandy and open, and the clayey soils of the western part of the Old Belt section, there is to be found almost every conceivable variation in shade, depth, and mechanical structure.

From a chemical standpoint, bright-tobacco soils are rather weak, as is to be expected from their high content of sand or silica, but most of them are very responsive to artificial enrichment by means of fertilizers, manure, and soil-improving crops. The relatively light soils which predominate in the New Belt section naturally are less well supplied with mineral plant food materials, particularly potash, than are the stronger soils of the Piedmont section. However, a soil possessing ideal mechanical and chemical qualifications may be entirely unsuited to tobacco unless it has good natural drainage, as it is ruinous to a tobacco plant to stand for any length of time in a water-logged soil.

In the earlier days of tobacco culture, before commercial fertilizers came into general use, it was the almost universal custom to plant tobacco on " fresh," or recently cleared, land. On such land

there is an accumulation of readily available plant food; the tobacco grows quickly, matures and ripens early, and cures well. In the Old Belt, therefore, where much of the soil tends to be too strong and clayey, a given soil, perhaps, will produce a crop of good color and quality when it is "fresh," but will not do so after it has been under cultivation for a number of years. But in the case of the light soils in the Coastal Plain section, those which have been longer under cultivation are preferable because the "fresh" land will make the leaves too thin and lifeless and the bottom leaves will begin to waste away prematurely.

CROP ROTATION SYSTEMS.

Aside from the natural character of the soil itself, there is no more important matter for the tobacco grower to consider than the management of his fields, so that in regular order they will be in the best shape for tobacco at the proper time. Indeed, the character of the tobacco produced will depend quite as much on how the fields have been handled in rotation between the successive tobacco crops as upon the fertilizer used or the cultivation given directly to the tobacco crop itself.

IMPORTANCE OF HUMUS IN THE SOIL.

Tobacco land should be so handled as to be kept in good life. A liberal supply of vegetable matter in an advanced stage of decay is highly desirable, but it should be of a kind not excessively rich in ammonia. For this reason the clovers, cowpeas, and other legumes, except in a limited way, generally can not be used with satisfaction preceding tobacco unless removed some two or three years from the tobacco, and on the stronger lands of the Old Belt section it would probably be best in most cases to omit them from the rotation altogether. Large quantities of slow-acting organic ammoniates tend decidedly against fineness, sweetness, and color.

It is well known that the organic matter of freshly cleared or broom-straw fields is of a kind well suited to tobacco. It consists principally of dead leaves, twigs, roots, pine tags, or broom straw and roots. Such vegetable matter, while poor in ammonia, by its ample volume makes the soil very mellow and friable and of good water-holding capacity. The weed growth that comes in spontaneously on the so-called rested fields is also generally of a kind suited to turn under as a source of vegetable matter for tobacco soils.

Supplying the necessary humus in this way perhaps may be considered satisfactory from the standpoint of the tobacco itself. In several other respects, however, it is very unsatisfactory. The rested field system of farming, if it may be called a system, means that a

part of the farm is at all times out of commission and not producing any profitable crop. It also means that many undesirable weeds and bushes are given every opportunity to reseed or reestablish themselves, and it gives the country the general aspect of being roughly and poorly farmed. As such it represents an antiquated, crude, and unsatisfactory type of farming from which we are now trying hard to get away.

In the New Belt section the growing of tobacco on freshly cleared land is unsatisfactory for the reason already mentioned, while in the Old Belt the proportion of the tobacco crop grown on fresh land is already small, and it is evident that it must in the future constitute a smaller and smaller proportion of the area planted to tobacco. On old land there is no more important problem in the production of fine, bright tobacco than how best to maintain in the soil a sufficient supply of the right kind of decaying vegetable matter, upon which its life and mellowness so largely depend.

Among the more satisfactory sources of vegetable matter for tobacco soils of the flue-cured district we may note the rye (or other small grain) fallow and the herd's-grass sod. Rye is in every respect satisfactory from the standpoint of its effect on the quality of the tobacco. It is thought well of by tobacco growers generally throughout the entire flue-cured district, but it is open to one very serious objection for general use as a crop to immediately precede tobacco. Its use necessitates the spring plowing of the land at a time when the teams are always rushed, and very frequently the land will be either too wet or too dry, or some other cause will too often prevent the proper fitting of the land early enough, or well enough, for the best results. When rye is used and turned under entire, it should not be allowed to get too tall and hard. It is best to turn it down when it is about knee high, and before being turned under it should be thoroughly cut into the soil by going over the field two or three times with the disk harrow, lapping halfway each time so as not to throw the field into ridges. The thicker and ranker the growth of rye, the more imperative it is that a thorough job be done with the disk before the land is plowed. If the rye is cut and removed from the field, the stubble should likewise generally be thoroughly cut to pieces with the disk before plowing the land.

GRASS IN THE TOBACCO ROTATION.

All things considered, there is probably no better humus crop for the tobacco rotation than herd's-grass or redtop, at least on practically all the tobacco soils of the Old Belt section and the stiffer soils in the New Belt. Aside from its value as a humus-yielding, soil-improving crop, suited to the tobacco rotation, redtop is a very valuable hay grass. It is suited to southern conditions and will give

a good yield of splendid hay, which may be utilized as a secondary source of money income on the tobacco farm, either through direct sale or indirectly through live-stock products.

For the best results with herd's-grass, the seed should be sowed from the middle to the last of August in the Old Belt and not later than September 20 in the New Belt Coastal Plain section. The preparation of the seed bed is a matter of prime importance in securing a good stand of grass. This is best accomplished without the turning plow, unless it be used some weeks or months before the grass is to be seeded. Instead, the field should be gone over with the disk harrow in July or August, followed by the smoothing or drag harrow just before sowing the seed. What is needed is a fine but shallow seed bed (preferably not more than 1 or 2 inches deep) with a firm under soil, and this condition can best be secured if the turning plow is not used. The place of the grass in the rotation, particularly in the Old Belt section, generally will be after wheat or oats, one of which has, in turn, probably succeeded the tobacco; that is, the grass will be seeded on wheat or oat stubble after the soil has been fitted during July and August, as mentioned. The disk should be started at the first opportunity after the grain is removed, so as to prevent the weeds from getting so large as to interfere with a satisfactory and economical fitting with the disk harrow.

Before seeding the grass, from 400 to 800 pounds of 3–8–3 fertilizer[1] or its equivalent should be broadcasted per acre. On the stiffer soils, if already in a fairly good state of fertility, the smaller quantity might suffice, but on the sandier soils, especially if run down in fertility, the larger quantity would be likely to give more satisfactory results. To insure an even stand of grass, the field should be gone over both ways in sowing, using a total of about 15 pounds of seed to the acre. After seeding, the field should be again gone over with the smoothing harrow, to lightly cover the seed, and then thoroughly rolled. Early in the spring, when the young grass begins to start, top-dress the field with about 200 pounds of nitrate of soda per acre, distributed in two applications about two weeks apart. The nitrate is best applied just before or during a rain, so that it will be dissolved, soak into the ground, and begin to feed the grass at once without any danger of injury by burning. After the lumps are crushed, the nitrate can be easily distributed directly by hand without increasing the bulk by mixing with sand or other filler. When making the second application of the nitrate, special attention should be given to any spots which, from the appearance of the grass, seem to have been missed in going over the field the first time. From this procedure a valuable hay crop of $1\frac{1}{2}$ to 2 tons or more

[1] The formula "3–8–3" refers to the percentage of ammonia, phosphoric acid, and potash, respectively.

per acre should result. Figure 1 shows the effect of nitrate of soda on grass grown in a tobacco rotation. The grass generally should be allowed to stand two years, when the sod may be turned down in the fall or winter in preparation for tobacco the next year. This fall plowing is a very important point, especially in the Old Belt, as it practically assures that the soil will be well fitted and early enough fitted to give the tobacco the best chance to do well.

OTHER CROPS OF THE ROTATION.

It is impracticable to attempt to lay out any definite rotation plan adapted to the needs of all tobacco farms. For the Old Belt section, however, where there is less diversity in so-called money crops, a rotation in which tobacco is followed directly by oats or wheat and

FIG. 1.—A field of grass showing the effect of nitrate of soda. On the right the grass was hardly worth cutting, while on the left, where nitrate of soda was used, a yield of nearly 2 tons to the acre was obtained.

then by two years of grass, as suggested above, would undoubtedly be found practicable and suited to the majority of tobacco farms. A number of possible variations from this plan will quickly suggest themselves. For example, if this system of cropping, supplemented perhaps by liberal fertilizing or manuring, tends to make the soil too rich for the best results with tobacco, the difficulty could probably be overcome by introducing corn into the rotation directly on the grass sod in place of the tobacco. A good crop of corn should result, and it would do much in the way of reducing the surplus fertility, for corn is an exhaustive crop, particularly on light land. This would lengthen the rotation to five years and bring the tobacco directly after corn. There is one serious objection to this plan. Corn frequently harbors large numbers of wireworms, which might

make it difficult to get a stand of tobacco because of the attacks of the wireworms on the young plants as soon as they are set out. This difficulty in turn could be successfully overcome by following the corn with oats, making a six-year rotation, the field coming back to tobacco again in the seventh year. Another variation would be to follow the tobacco with corn and then with oats or wheat, to be followed in turn by the two years of grass, making a five-year rotation and putting the tobacco on the grass sod, as in the four-year rotation first mentioned.

In the New Belt there is a greater diversity of money crops. Cotton, peanuts, and sweet potatoes may be mentioned, and among these cotton would be the one most generally desired because of its ready market and wide adaptability throughout the New Belt section. Legumes are also much less objectionable on the light Coastal Plain soils, and in many instances a legume could be introduced into the rotation with benefit. In most cases cowpeas probably would be found most satisfactory for this purpose, or, on the stiffer soils where it will hold through the winter, crimson clover also might often be used to advantage. When used, these legumes should generally come in the rotation closely succeeding tobacco, so that any excess of ammonia which they might supply could be used up to some extent by the crops intervening before the field comes to tobacco again. On some of the very lightest unimproved soils, tobacco might give good results even if directly following a turned-under leguminous crop, such as cowpeas.

On the stiffer soils of the New Belt, the four-year rotation suggested for the Old Belt, namely, tobacco followed by winter oats and then two years in herd's-grass, would be practicable in some cases. If it is desired to put cotton in the rotation, satisfactory results should be obtained by seeding the field to cowpeas as soon as the oats are removed. The peas should be fertilized liberally with phosphoric acid and potash (say, 200 to 400 pounds of 16 per cent acid phosphate and 100 pounds of sulphate of potash), and the peas could either be mowed for hay or turned under, generally the latter when it is desired to improve the soil, as the condition of the field or the need for the hay makes most desirable. The cotton could follow the peas, after which the field could be planted in tobacco again, making a three-year rotation. If the pea vines were turned under, this system ought to keep the soil well supplied with vegetable matter, and good crops of both cotton and tobacco should result with the addition of but comparatively small amounts of nitrogen in the fertilizer. The oat crop should be top-dressed early in the spring with about 200 pounds of nitrate of soda per acre, in the manner recommended for grass.

Peanuts or sweet potatoes could be introduced into the rotation if desired, either in place of or succeeding the cotton. Peanuts are

a leguminous crop, but since both the vines and the roots are removed in harvesting (unless used for grazing hogs) they may be considered an exhaustive rather than an improving crop. Sweet potatoes, however, leave practically everything on the field except the potatoes themselves, which are principally starch, and this crop, therefore, tends to improve the soil. The vines decay very rapidly and their plant-food content, although rather small, soon becomes again available. Here again the rotations mentioned are to be considered only as suggestive, and any number of variations will readily suggest themselves to the thoughtful farmer; but the importance of maintaining a bountiful supply of vegetable matter of a kind not too rich in nitrogen at the time the field comes in tobacco should always be kept clearly in mind when planning the rotation.

FERTILIZERS FOR FLUE-CURED TOBACCO.

Bright-tobacco soils as a class are naturally rather infertile; but they are light and friable and of a character to respond readily to fertilizers, particularly in producing a crop of high money value like tobacco. Fertilizers increase the chances of profit from growing bright tobacco in two ways. They greatly increase the yield, sometimes by 100 per cent or more, and if properly balanced they generally improve the quality. Because of the natural deficiencies of bright-tobacco soils and because of the special adaptability of commercial fertilizers to bright tobacco there are no other types of tobacco produced in this country on which fertilizers are so freely used, except on some of the high-priced cigar-wrapper types in New England and Florida.

A so-called complete fertilizer—that is, one containing each of the three materials, ammonia (nitrogen), phosphoric acid, and potash—is generally needed, and the maximum yield can not be secured unless each is supplied in sufficient quantity. No general rule as to the proper proportion or balance between these materials can be given, and the farmer must exercise judgment in the matter. The best proportion for the three elements is likely to vary considerably on different fields, according to the soil and its state of improvement. As stated, each of these elements has its effect in limiting the yield; but, aside from this, there is, broadly speaking, a special effect on the quality of the leaf that may be attributed to each element. Too much ammonia, especially if unsupported by a sufficiency of the other fertilizing compounds, particularly phosphoric acid, will make the tobacco coarse, dark, and late in maturing, with a tendency to damage by "red fire" or dead spots here and there on the leaves. Without a sufficient supply of ammonia, however, the tobacco will be small, thin, and poor, although the color may be good.

Potash, like ammonia, improves the body of the leaf, and it has a decided value in tending to diminish or prevent "diseasing" or "specking." On the light, sandy soils of the New Belt section especially, potash should be applied much more liberally than is now the general custom.

Phosphoric acid may be considered the most generally needed plant-food material throughout the tobacco-growing region under consideration. It not only increases growth but hastens maturity, and also strongly tends to brighten the color because of its decided effect in ripening the leaf. By reason of this specific effect in thus improving the quality phosphoric acid should be used liberally in the tobacco fertilizer, particularly on the better improved soils, which, from an accumulation of nitrogenous materials, might tend to produce a dark, coarse leaf. On the other hand, some caution should be exercised not to use it excessively on unimproved very light soils. On such soils there is natural danger from premature ripening, or "firing," as it is usually called, and such tendency would be increased by an excessive application of phosphoric acid, though increasing the ammonia supplied in the fertilizer or otherwise would tend to overcome this difficulty with probable increased growth as well. This largely explains why the turning under of a leguminous crop immediately preceding tobacco on such unimproved very sandy soils may sometimes result in positive benefit.

Generally speaking, phosphates (except as just indicated) and potash may be used freely on flue-cured tobacco without injury to the quality, but it requires nice adjustment of the ammonia supply to give the best results. As stated, too little will make a "poor," thin tobacco of small growth, while too much will tend to make the tobacco dark, coarse, and rank smelling. Ammonia in the soil comes almost entirely from decaying vegetable matter or manure, and the quantity of ammonia to be used in the fertilizer will depend largely on how much may be expected from these sources in the soil. A crop of 1,000 pounds of tobacco to the acre, to produce the leaf, stalk, and roots, will need to assimilate about 75 pounds of ammonia (equivalent to approximately 62 pounds of nitrogen). On poorly improved sandy soils, generally producing around 600 pounds of tobacco to the acre under ordinary fertilization (say, 500 pounds of 3–8–3 fertilizer to the acre), the yield and quality generally could be improved greatly and the crop made more profitable by using an increased amount of ammonia in the fertilizer. On such a soil, out of the 75 pounds of ammonia necessary to produce a 1,000-pound crop it would not be unreasonable to supply in the fertilizer 40 or 50 pounds of this material (equivalent to 250 or 300 pounds of 16 per cent dried blood).

Both phosphoric acid and potash are generally needed on practically all the tobacco soils of the flue-cured district, although potash is perhaps of somewhat less importance on the stronger soils of the Old Belt section. Neither of these materials is likely to do harm, and any unused portion will not be lost by leaching (except possibly on some of the very deep loose sands of the Coastal Plain section) but will remain to benefit succeeding crops of the rotation. It would undoubtedly be wise, therefore, to use these materials somewhat more freely than has been customary. In the New Belt this recommendation would apply more particularly to potash, because the soils there are relatively more deficient in that constituent, while in the Old Belt, particularly on the more clayey soils, phosphates are more urgently needed, although a considerable increase in the potash used, particularly on the lighter soils, would also be desirable.

For general use it would seem reasonable to recommend as a base the use of from 400 to 600 pounds of 16 per cent acid phosphate per acre and in the Old Belt about 100 pounds of sulphate of potash (analyzing 48 to 50 per cent actual potash, K_2O) or for the lighter soils of the New Belt 150 to 200 pounds of the sulphate of potash per acre.

The amount of ammonia to be used with these quantities of phosphoric acid and potash, as indicated above, would depend largely on the condition of the particular field under consideration. In general, it may be stated that proportionately more ammonia can be used profitably on the light sandy soils of the New Belt than on the stronger Old Belt soils. Another factor of importance, particularly in the western part of the Old Belt section, is the time of harvesting and curing. If the crop ripens and is cured in warm weather, say, up to September 10, the tobacco will naturally tend to yellow well and cure bright, as compared with the same tobacco harvested and cured in the cool weather of late September and October. The normal period for curing tobacco in the New Belt is during July and early in August, which are hot-weather months, and this is a factor distinctly favorable to a good bright cure. Tobacco that ripens and cures during hot weather, particularly if the soil be rather dry, can satisfactorily utilize a larger amount of ammonia than when the harvest is in cool weather, and wet weather just before the tobacco is harvested is an additional adverse factor. Increasing the phosphoric acid, as noted above, will tend to brighten the leaf and thus overcome some of the harmful effects of too much ammonia.

In the Old Belt section under average conditions, particularly on the stronger type of soils of the western part, probably about 150 pounds of 16 per cent dried blood (or its equivalent in some other good ammoniate) would give approximately the right proportion of

ammonia for the minimum amounts of phosphoric acid and potash mentioned above. The formula would be as follows:

	Pounds.
Dried blood, analyzing 16 per cent ammonia	150
Acid phosphate, analyzing 16 per cent phosphoric acid	400
Sulphate of potash, analyzing 50 per cent potash (K_2O)	100
Total	650

Such a mixture, while weighing only 650 pounds for an acre of land, would, in the quantities of plant food carried, be approximately equivalent to an 800-pound application per acre of a fertilizer analyzing 3 per cent ammonia, 8 per cent phosphoric acid, and 6 per cent potash. If desired, cottonseed meal (analyzing 7½ per cent ammonia) might be substituted for the blood, using twice the number of pounds; or nitrate of soda (analyzing 18 to 19 per cent ammonia), at the rate of about two-thirds the number of pounds of blood, could be used. Generally speaking, however, cottonseed meal is somewhat less active than blood on the basis of equivalent quantities of ammonia, while there may be some question whether nitrate of soda does not affect unfavorably the quality of the leaf produced.

The cost of the 650 pounds of fertilizer shown in the formula will vary somewhat from year to year, but will generally be about $10. In certain cases, of course, as when the soil had been considerably improved by the use of manure or leguminous crops, even a smaller quantity of ammonia than here mentioned might give better results. In extreme cases, especially when color is an important factor, the ammonia might be omitted altogether. On the other hand, in the case of the lighter types of soil in the Old Belt, particularly in the eastern part of that section, where the lighter types of soil predominate, the proportion of ammonia in the fertilizer generally could be somewhat larger than that shown in the above formula. For these conditions 200 pounds of blood, or even more in some cases, might be a better balance and prove more profitable.

In the New Belt section, with the combination of still lighter and weaker soils and early harvesting in warmer weather, a materially richer fertilizer could undoubtedly be used to advantage in most cases, and for that section a mixture may be recommended for average conditions composed about as follows:

	Pounds.
Dried blood, analyzing 16 per cent ammonia	250
Acid phosphate, analyzing 16 per cent phosphoric acid	500
Sulphate of potash, analyzing 50 per cent potash (K_2O)	150
Total	900

This mixture of 900 pounds for an acre of land would be equivalent in plant-food value to a 1,000 pound per acre application of a

fertilizer analyzing 8 per cent of phosphoric acid, 4 per cent of ammonia, and 7½ per cent of potash. On the very lightest soils of the New Belt section, for reasons already mentioned, better results might be obtained by reducing the phosphoric acid, say, to 400 pounds, or by increasing the blood (ammonia) to 300 pounds or more, thus narrowing the ratio between the ammonia and phosphoric acid to 5 or 5½ to 8 instead of 4 to 8 as shown in the formula as given.

Fertilizers for tobacco are generally applied in the row, and when used in the ordinary quantities better immediate effects are no doubt realized. When considerable fertilizer is used in the row, however, even in the quantities mentioned above, it should be thoroughly incorporated with the soil by running a double-shovel plow with narrow teeth along the row before it is bedded. When large quantities of fertilizer are used, it might be best to apply at least half broadcast. In connection with the use of fertilizers, it is assumed that the humus supply has been given due consideration, thus insuring a good physical condition and moisture-holding capacity. A tight, drought-stricken, or badly drained soil can not be expected to become very productive just by increasing the supply of plant food in the form of commercial fertilizers.

In the above discussion no special mention has been made of the relative value of the different sources from which the plant-food materials may be derived, and this has purposely been omitted for the sake of brevity. It should be stated, however, that the materials mentioned may be regarded as standard, in the light of our present knowledge, and as good as anything now on the market.

As a source of potash, however, the sulphate should generally be given the preference in a tobacco fertilizer. The other materials most likely to be used as a substitute are muriate of potash and kainit. Both of these materials contain large quantities of chlorin, which has a tendency to make the tobacco burn poorly. Complaints have frequently been made as to the poor burning quality of flue-cured tobacco, particularly in respect to tobacco from the New Belt section, and it would be unwise to use anything in the fertilizer which would tend to strengthen the basis for this criticism.

BARN MANURE FOR FLUE-CURED TOBACCO.

While commercial fertilizers are and of necessity must remain the chief reliance of the tobacco grower, barn lot or stable manure is used to some extent on bright tobacco, although it has opponents as well as advocates of its suitability for this crop. In so far as its use may be considered objectionable, the objection has the same basis as that of other organic materials overrich in ammonia, namely, the tendency to make the tobacco coarser and darker. The lighter and poorer the land in respect to other ammoniates, the more likely is the

manure to be found desirable and advantageous. The way in which the manure is used is also an important factor in determining its effect on the quality of the crop. If well rotted and applied some months before the tobacco is planted, it can generally be used in moderate quantities with decided benefit, except, as already indicated, on lands already abnormally rich in ammonia. Where possible, it should be applied the fall before planting the tobacco, and certainly not later than the first of March. When used at the rate of 2 or 3 tons to the acre it can be applied in the row. When used in larger quantities (5 or 6 tons per acre is about as heavy as it is generally advisable to use manure for bright tobacco as a direct application), it should be broadcasted over the land and either harrowed or plowed in. Only fine, well-rotted manure should be used in the row, and it should be applied as much as two months before planting if possible. In using manure in this way the rows may be laid off in February or early in March and the manure put out and covered with the turning plow. Just before planting time these rows may be reopened with a single-shovel plow, the additional fertilizer applied, and the land rebedded in preparation for setting the tobacco.

Where tobacco succeeds herd's-grass in the rotation, an excellent method is to apply the manure to the grass during the winter before the last season the field is to stand in grass. This would greatly help the hay crop and give the manure time to become thoroughly decomposed and incorporated with the soil.

THE USE OF LIME ON FLUE-CURED TOBACCO SOILS.

Most flue-cured tobacco soils contain sufficient lime to fill direct plant-food requirements, but not enough generally to keep them from becoming rather acid. Their general crop-producing power through enhanced bacterial efficiency would usually be improved if they were occasionally limed. The grass especially would yield much better if lime were occasionally used. The direct effect of lime on the tobacco, however, may be somewhat injurious to the quality. By hastening the decay of the vegetable matter in the soil it increases the ammonia supply, and on soils already tending to be overrich the lime will tend still further to make the tobacco dark and coarse, the same as if an increased supply of ammonia were rendered available in any other way.

On some very poor soils, however, lime might result in both a larger yield and better quality because of the increased food supply rendered available.

It is somewhat a matter of controversy, also, whether lime does not tend to injure the burning quality of tobacco. When lime is used in the tobacco rotation it seems wisest, therefore, to use it immediately after the tobacco comes off and before the wheat or oats are

seeded. It would thus tend to help the immediately succeeding crops, particularly the grass, and would be largely out of the way, so far as its direct effect is concerned, by the time the field is again planted to tobacco. On tobacco lots, lime should not be used ordinarily oftener than once in about four years and at a rate not to exceed one-half ton of quicklime or its equivalent per acre.

VARIETIES OF FLUE-CURED TOBACCO.

A great array of so-called tobacco varieties might be listed, but many of them would represent but little, if any, real variation in type. There is, however, one broad differentiation among the many so-called varieties, based on shape and size of leaf, which can be readily observed. Thus we have the broadleaf types, represented by such standard sorts as Warne, Yellow Oronoco, White-Stem Oronoco, Big Oronoco, Adcock, Adkin, Willow-Leaf, Gooch, Tilley, and Hester, and the narrow-leaf sorts, as Narrow-Leaf (little) Oronoco and Flanagan.

Throughout the New Belt and on the lighter soils of the Old Belt section the broadleaf types are generally preferred, as they are better adapted to the production of smokers, cutters, and wrappers. On the stronger soils of the western part of the Old Belt section, particularly westward from Rockingham County, N. C., and Henry County, Va., the narrow-leaf sorts are general favorites. These narrow-leaf varieties will make good, rich filler on suitable land, and by somewhat closer planting on improved land a large yield per acre can be grown without the individual leaves becoming overgrown and coarse. Flanagan and some of its subtypes, particularly the Improved Flanagan, are rather large-leaf types, about midway between the narrow-leaf and the broadleaf sorts, and are well adapted to quite rich land. The variety known as Short-Stalk Flanagan closely resembles the Narrow-Leaf Oronoco. The Flanagan types are perhaps the most vigorous growers and heaviest yielders of any of the flue-cured varieties, but they are a trifle later in maturing than the others.

On the fine, bright soils the broader leaf types are generally most popular. The Warne, a standard wrapper type, is perhaps the most popular of any. The White-Stem Oronoco, Willow-Leaf, and Gooch are favorites in certain parts of the New Belt section. The Adcock is a great favorite in the noted wrapper-producing section in the southern part of Granville County, N. C. The Adkin is also a popular broadleaf sort in certain sections of the Old Belt and has the merit of being some days earlier in maturing than most of the other standard sorts, but this earliness is probably somewhat at the sacrifice of yield.

The distance between the leaves on the stalks is somewhat greater on these broadleaf types than on the narrow-leaf sorts, the spacing being particularly wide in the case of the Adcock. It should be noted, perhaps, that any of these varieties will have the leaves more closely or wider spaced according to the nature of the soil, especially in respect to moisture conditions. With an abundance of moisture the spaces between the leaves will be wider, and under droughty conditions the leaves will be crowded much more closely together. This is a general principle in respect to all vegetation.

FIG. 2.—A seed head of tobacco covered with a paper bag to prevent mixing.

SELECTION AND CARE OF SEED PLANTS.

In selecting seed plants, close attention should be given to all the points that go to make up the ideal plant, according to the standard which the grower should have clearly in mind. The largest plants in the richest part of the field are not necessarily the best for seed purposes.

Pure strains of seed can be saved with certainty only by covering the seed head during the blossoming period so as to prevent mixing or crossing with inferior plants or suckers by the passing of insects from flower to flower on different plants. For this purpose an ordinary light-weight but strong paper bag of about the 12-pound size, such as can be obtained at any grocery store, is most practical. A day or two before the first flowers open the bag should be tied about the head (fig. 2), which first has been trimmed to a "crow-foot." The bag should be loosened and raised up every few days, as the seed head grows, and the

flower débris shaken out. After all the flowers of the crow-foot are opened and the seed pods begin to swell, the bag may be removed if desired, but it will be necessary to keep all other flower branches and buds constantly picked off.

In harvesting, only the fully matured and ripe pods should be saved. Such as are underripe should be picked off and discarded. After they have been shelled out, the lighter, imperfect seeds should be got rid of by some simple winnowing device, for the same reason that wheat or other seed are cleaned of inferior grains before sowing. A satisfactory separation of the seeds can be made also by settling them in a glass of water. After half or two-thirds of the seeds have sunk to the bottom, at the expiration, probably, of two or three hours, the floating seeds may be skimmed off and the heavy seeds that have settled can be dried on blotting paper.

PREPARATION AND CARE OF THE SEED BED.

It is the almost universal custom throughout the entire flue-cured district to prepare the seed bed on freshly cleared land, either in the woods or in some other suitable location. The reason for this is that there is an abundance of humus in such land. It is not compacted and baked by heavy rains and the sun, and the plants grow faster on fresh land than on old land.

The particular spot of land chosen should be loamy and mellow and naturally moist, but having good drainage and free from standing water at all times. It is desirable usually to locate the bed near a stream of water. At such places the land is apt to be naturally moist, and in the event of an extreme drought the bed can be more readily watered artificially.

An exposure to the south or east will give the earliest plants, although it is best to have at least two beds, one a little later than the other. The spot chosen should also be as free from weeds or grass as possible, and generally, as further insurance against a weedy bed and to kill soil insects as well, the bed should be burned during the winter before it is seeded. If plenty of good dry brush is available (pine brush is best) the bed can be most easily and cheaply burned with this material. Usually it is necessary to haul the brush at least a short distance. This can best be done by piling it compactly on a 12-foot wagon frame. About eight good loads of well-compacted brush will usually be required for a bed of 100 square yards. Before the brush is piled on the bed, the leaves or other litter should be raked from it, as they hold moisture and would tend to prevent the heat from penetrating the soil to a sufficient depth. If brush in sufficient quantity is not available or it is desired to burn the land very thoroughly, a combination of wood and brush may be used. Burning in this way will require about 3 cords of wood for 100 square

yards. Long poles or skids are laid along the ground at intervals of about 4 feet. Across the ends of these skids on the upper side of the bed, brush and wood is piled about 4 feet wide and 3 feet high. This pile is set on fire in several places. With considerable attention it will generally burn down sufficiently in about a half hour. The embers are then pulled down with hoes or hooks with long handles to the adjacent strip 4 or 5 feet wide just below. The fires are renewed by piling on more wood and brush and allowed to burn down for another half hour, or until the soil beneath seems well heated and dried out to a depth of about 3 inches. This process is repeated until the whole bed is gone over.

A spell of dry weather when the ground is free from frost should be chosen for burning. If the soil is wet, it will take much more heat to burn with the same efficiency because of the increased amount of water to be evaporated, and in some cases the physical condition of the soil might be injured by burning when the soil is too wet. The bed may be burned at any suitable time during January or February, or even as late as the middle of March in the western part of the Old Belt section. The burning of the soil puts it into good tilth, and generally it can be worked up and sowed to best advantage at that time. A disadvantage is the danger of washing the seeds away by heavy rains or that they may sprout prematurely during protracted warm spells in the winter months and be killed by later cold snaps. This latter incident, however, is a rare exception, and generally the seed will not come up till about the last of February or first of March in the New Belt section or about the middle of March in the western part of the Old Belt. In fitting the bed after burning, or if fitted without burning, as is sometimes done on weed-free land, a single-shovel colter plow is of great service. After raking off the embers the bed should be gone over both ways with the single-shovel plow and then gone over several times with a drag harrow. This will minimize the amount of handwork required in fitting to a fine surface tilth. Fertilize liberally by raking in about 1 pound per square yard of some good fertilizer such as 3–8–3 or its equivalent. If the bed has been burned, the ashes will give enough potash, but phosphoric acid and ammonia will be required. Blood or cottonseed meal are good forms in which to apply ammonia at the time of seeding, but about the time the plants should come up a top-dressing of nitrate of soda, at the rate of about 5 pounds per 100 square yards, will start the plants to growing vigorously. Unless absolutely necessary, nitrate of soda should not be applied to a plant bed after the plants have attained much size, because it will force them into a late tender growth at transplanting time and they will not be sure to live.

A moderately heaping tablespoonful of good seed is enough to sow 100 square yards of bed. If too much is used the plants will be

spindling from being too thick, and they will not thrive when transplanted. This quantity of seed should be mixed with about 1 peck of some good bulky material, such as fine, dry fertilizer. In sowing, the bed should be gone over both ways in order to insure an even distribution. One of the best methods of covering the seed is by tramping with the feet. This compacts the soil and presses the seed slightly into it. If the bed is sufficiently smooth, a hand roller might be used, but it would not usually be practicable for use on an ordinary bed in the woods.

After danger of snow is over, not later than about 10 days before it is time for the seed to come up, the bed should be boxed in tightly with poles or plank about 6 inches high and covered with plant-bed cloth. The cloth will retain the warmth and make the plants earlier and, if tight all around and free from holes, will keep out flies and other insect enemies. The cloth is kept from sagging to the ground by stretching wire on poles across the bed at intervals of about 5 steps, or by placing wickets made from green switches here and there over the bed.

About the time the plants begin to come up it is a good plan to sow an additional half tablespoonful of seed over the bed on top of the cloth. The rains will carry the seed through the cloth into the soil and this extra seeding will make a good late drawing of plants which may prove useful, and in any case will not interfere with the first sowing.

If the bed gets weedy it must be picked over by hand, preferably during a spell of wet weather. A few days before transplanting, the cloth should be removed to harden the plants, or this may be done earlier if the plants are becoming overgrown.

Always to have an abundance of plants when needed is a fundamental factor for success in tobacco growing. Without plants the whole year's work is a failure. A good bed may supply as many as 40,000 or 50,000 plants from 100 square yards in two or three drawings, but it is not safe to count on more than 10,000 to 15,000 plants from each 100 square yards sowed. A plant bed with the cloth removed and plants ready for transplanting is shown in figure 3.

EARLY AND LATE PLANTING COMPARED.

The transplanting season in the New Belt section begins early in April in South Carolina and continues until as late as the middle of June in the western part of the Old Belt, although even in this latter section the main plantings are made from about the middle to the last of May. In the New Belt the bulk of the crop is generally set by May 1. The tobacco which reaches maturity and is harvested while the weather is yet warm, say, from the middle of August to the middle of September in the western part of the Old

Belt section, generally will be decidedly better in quality, particularly in respect to color, than the later cuttings. In the New Belt and the eastern part of the Old Belt the harvest season, running through July and August, naturally comes in warm weather, and this is a distinct advantage, but even there the earlier curings are likely to be best in quality. Fairly early planting is to be preferred, therefore, even in that section, and the plants live better if transplanted before the weather becomes too hot and dry. But in the western part of the Old Belt the grower should make a strenuous effort to have an early crop by planting early and by choosing land on which the plants will grow quickly.

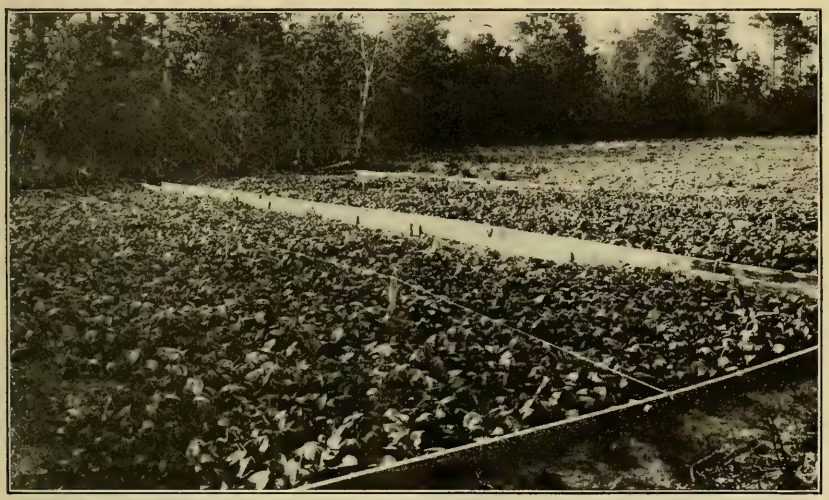

FIG. 3.—A bed of tobacco plants, with the cloth cover removed, ready for transplanting.

PREPARATION OF THE SOIL FOR TRANSPLANTING.

As already indicated, the best system of tobacco farming, particularly in the Old Belt, will provide for the fall or winter plowing of the tobacco land. The winter freezing will mellow the soil and the winter and spring rains will be better held for the use of the growing crop during the summer. Little faith should be placed in the oft-heard assertion that shallow plowing (3 or 4 inches) is best for tobacco, although in the Old Belt it probably would be unwise to turn up any considerable quantity of a stiff clay, but unless a field can be plowed as much as 6 inches deep without so doing, it is probably not well suited to bright tobacco.

If the field has been fall or winter plowed no further preparation will be necessary in the spring until it is time to fit the land for transplanting. The disk harrow is the best implement for working the soil into a good tilth, if followed by a drag harrow just before laying off the rows.

DISTANCE OF PLANTING.

The space allowed each plant in the field, that is, the distance of planting, is a matter of considerable importance in determining the quality and to some extent the yield of tobacco produced. Careful attention should be given the matter of proper spacing when setting out the crop, and a strenuous effort should be made to secure a good, even stand over the whole field as promptly as possible. The real importance of this matter will be clear by observing the effects of a broken stand of plants on an improved field just before the harvest. Where the stand is regular the tobacco will probably be smooth and fine and ripened nicely. But where some of the plants are missing the surrounding plants will be overgrown and coarse and will neither ripen, yellow, nor cure well. Because of the increased feeding space, without competition from other plants, they are overfed and rendered overgrown and coarse and of greatly diminished value.

In the flue-cured district the customary distances of planting give about 4,000 to 5,000 plants to the acre. In the New Belt it is more usual to space the rows about 4 feet apart, with the plants from 2 to 2½ feet apart in the rows; and in the Old Belt, particularly in the western part, the more common distance between the rows is 3½ feet, with the plants from 2½ to 3 feet apart in the rows. The reason for the wider spacing of the rows in the New Belt doubtless is largely because of the greater convenience in getting through the wider rows with the mule and truck used at harvest time for hauling out the leaves, and also because the tobacco grows taller and would thus tend to more self-shading in the narrower row. In some sections of the New Belt it is customary to make every eighth row 6 inches wider than the others, and at harvest time the mule draws the truck or slide, into which the leaves are put, through this wider space with less danger of breaking the tobacco standing in the rows on either side.

As the soil becomes richer by better farming methods, much of the tendency for the tobacco to grow coarse and dark can be overcome by thicker planting combined with somewhat higher topping. In some cases 3½ feet between the rows and 2 feet between the plants in the row would not be too close for the best results in yield and quality.

LAYING OFF THE ROWS AND TRANSPLANTING.

For laying off the rows the bull-tongue single-shovel plow is a good implement. After distributing such fertilizer as is to be used in the row, it should be incorporated with the soil by going along the row with a double or single shovel plow or other suitable implement, after which the rows are bedded by turning two furrows together with a 1-horse plow. In a few sections a 4-furrow bed is

made, on the theory that the wide bed holds the moisture better and gives the plant a better start. In most sections, however, the consensus of opinion seems to be that the 2-furrow bed is just as satisfactory. In the light soils of the New Belt the bed is put into final shape for planting by dragging down and slightly packing the top of the ridge. A cotton planter drawn along the row is frequently used for this purpose, the plow in front serving to knock off and flatten the ridge while the roller behind compacts it. A plank or log drawn by a mule and wide enough to cover two or more rows at a time is also a satisfactory device. Figure 4 shows an ingenious implement for this purpose devised and used by Mr. B. F. William-

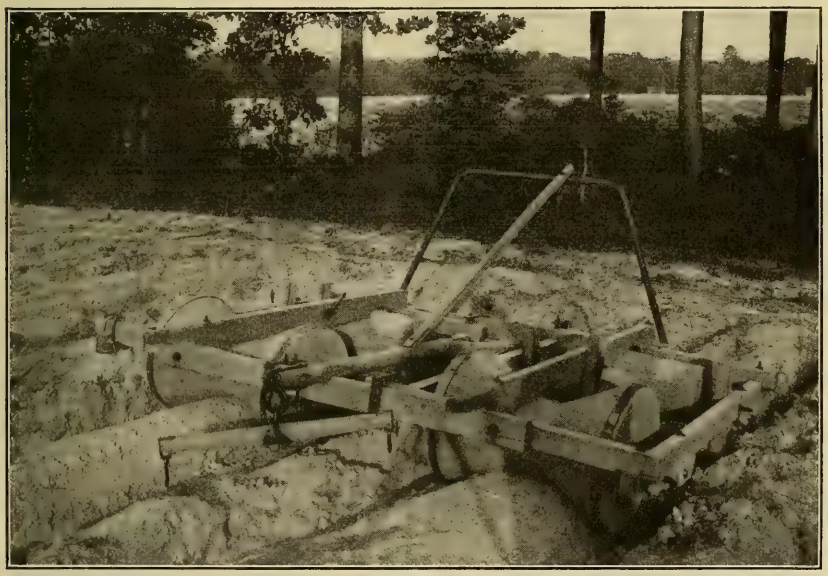

FIG. 4.—An ingenious form of ridge leveler, for compacting and leveling the beds or lists upon which tobacco plants are to be transplanted.

son, a noted grower in Darlington County, S. C. This device, by means of the spool-shaped rollers on the front, rounds off the bed so that water can not form pools and drown the plants, and it flattens and compacts the bed at the same time.

On the rougher soils of the Old Belt section it is more customary to go over the field with a hoe, cutting through the bed and making a pat at each spot where a plant is to be set. The objects of the bed are to get a body of good, soft soil in which to set the plant and to provide that surface water during heavy rains may flow away from the plant and not stand around it and either cover it with silt or drown it outright. But in attaining these objects the less the elevation of the plant the better.

When transplanting, so far as possible use only good, strong plants of uniform size. The plants should be kept straight and the roots well mulched and protected from the drying wind and sun in order to retain their vitality as much as possible, which will help materially in insuring a good start in growing. In the flue-cured districts the greater portion of the crop is transplanted by hand in a natural season, using a peg for making holes and pressing the earth to the roots. But more or less setting with water in times of drought is resorted to almost every year in some sections. For this purpose a special hand planter is often used. This is an effective and inexpensive implement. It has the merit of putting the water imme-

FIG. 5.—A 2-horse machine transplanter at work. A machine of this kind may be seen here and there in the flue-cured tobacco district, particularly in the New Belt section.

diately around the roots where needed, and it is thought that the plants grow better than when set and hand watered with dippers. The 2-horse machine setter is in use to a limited extent in some neighborhoods, but, of course, is adapted only to smooth fields and soft land. A view of one of these machine setters at work in Snow County, N. C., is shown in figure 5. The expense of machine setting is about the same as for hand setting, but there is the advantage of being able to go ahead with the setting when the plants are right, independently of the weather. The water is put at the roots and the plants live as well or better than hand-set plants.

In from three to five days after the field is set out it should be gone over again and carefully replanted with the best plants avail-

able. A strong effort should be made to secure a perfect stand as soon as possible. This is a very important point in securing the best results from tobacco.

CULTIVATION OF THE GROWING CROP.

In order to encourage a quick start in growing, a good horse cultivation and careful hand hoeing should be given the newly set tobacco as soon as it has become established, generally after a week or ten days. A little fresh earth should be drawn about each plant, but care should be taken not to loosen the newly established roots. A second hand hoeing may be needed about two weeks later; but in any case the young tobacco should be horse cultivated every week or ten days, according to conditions, until about topping time. After topping, cultivation should be discontinued, as the tobacco will ripen better if the cultivation is not continued too late. From four to six horse cultivations can generally be given to advantage, although many growers usually give but three. If the soil is at all hard, the first one or two cultivations should be deep, to thoroughly loosen up the soil and render it mellow. A double-shovel plow with narrow teeth is useful for this purpose. Later on, as the roots begin to spread through the row, only shallow cultivation should be practiced. For these later cultivations especially, the ordinary 5-toothed cultivator, fitted with an 18-inch or 20-inch sweep on the rear tooth, is a very satisfactory implement. The sweep attachment fills the furrows made by the teeth and works the soil toward the plant. Such a slight raising of the soil along the row is undoubtedly desirable; but it is open to question whether the excessive bedding of the row with the turning plow, as commonly practiced in "laying by" the crop, as it is called, at the last cultivation is desirable, except perhaps in very wet years or on soil characterized as wet or "spouty."

DISEASES AND INSECT ENEMIES.

Specking, or "diseasing," as it is generally called, is the most common disease injury to which tobacco in the flue-cured district is subject. It is believed to be a fungous disease, disseminated by spores, perhaps of several species. The trouble is favored by a moist atmosphere and by sappy tobacco. The only practical method of reducing the injury from this trouble, so far as known to the writer, is by using potash more liberally in the fertilizer, which seems to increase the resistance of the plant to the disease.

Root-knot, caused by nematodes or eelworms of semimicroscopic size, also does great damage, particularly on some of the lighter soils of the New Belt section in South Carolina and North Carolina. Nematodes also attack a long list of plants other than tobacco, and

the only way to free a field from the pest is by absolutely clean fallow cultivation for a year or two or by growing only immune crops for two or three years so as to starve them out.[1]

The Granville wilt, first observed in the eighties of the past century, is a bacterial disease communicated through the soil. In the flue-cured district the infested area so far as known is largely confined to one soil type in the southern part of Granville County, N. C. This soil naturally produces a very fine type of wrapper tobacco. The disease is spreading quite rapidly locally and now occupies a considerable area in that section, embracing one of the very best bright-tobacco areas which we have. Once the soil is infected, no practical means have yet been devised for controlling the disease, and it is difficult to prevent it from gradually spreading to other adjoining areas. While the disease is confined to a comparatively restricted area, it is, nevertheless, a very ruinous one in that section.

The mosaic disease, frequently spoken of as calico or "mottling," probably is the most widespread of all the tobacco diseases. Until recently it has been quite generally supposed to be simply a manifestation of malnutrition, caused by unfavorable growing conditions. It has long been known to be infectious, however. It can be spread, for example, by rubbing the leaves of a diseased plant and then likewise rubbing the leaves of healthy plants. Recent tests by Mr. H. A. Allard, of the Office of Tobacco and Plant-Nutrition Investigations, Bureau of Plant Industry, go to show that the disease is a specific infection and in the absence of such infection can not arise from impaired nutrition. It has been discovered that certain aphids or plant lice are largely responsible for the dissemination of the disease. Other names, such as frenching, walloon, etc., are applied to a group of diseases resembling true mosaic more or less. Such diseases as the so-called "sore-shin" and "rotten-stalk" are sporadic and occasional in their appearance, and are thought to be due primarily to some mechanical injury which may admit disease germs that attack the tissues locally.

The occurrence of so-called "dead spots" here and there over a field, particularly in the Old Belt section, in which the plants, without apparent cause, fail to make any growth, is a phenomenon frequently observed, especially in a dry summer following a very wet spring. The soil of these spots generally appears to be in as productive a condition in all respects as other parts of the field. The roots of the plants show no apparent injuries of any kind or evidences of disease. No fully satisfactory explanation of the cause or means of remedying the trouble are known to the writer.

[1] For a full discussion of nematodes and methods of eradication, see "Root-Knot and Its Control," U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 217, 1911.

Tobacco at various stages of its growth is subject to the attacks of a number of insect enemies, for a list of which, with recommendations for controlling them, the reader is referred to Farmers' Bulletin 120 and to circulars 123 and 173 of the Bureau of Entomology.

TOPPING AND SUCKERING.

In about eight or nine weeks after transplanting, in seasons of normal growth, the tobacco plants will begin to show signs of sending up a seed head, "buttoning out," as it is called. The topping season is now at hand. In topping, the aim is to improve the quality of the leaves produced and to aid the different plants in maturing at the same time. Experience and judgment are necessary in this important operation. From 8 to 12 or more leaves, excluding undeveloped leaves at the bottom, are commonly left to mature on each plant. Primarily the number of leaves that should be left depends upon the richness of the soil and the vigor of the plant. If the plant is topped too low the yield will be unnecessarily sacrificed and the remaining leaves will be coarse and overgrown. Sometimes in the Old Belt section some of the inferior bottom leaves are primed (broken) off and discarded at the time of topping the plant. In the New Belt, where harvesting by picking the leaves is general, it is customary to top somewhat higher than in the Old Belt, often to as many as 16 or 18 leaves.

The time required for a plant to mature depends somewhat on the number of leaves left on it. In order to bring as many plants as possible to a uniform state of ripeness at one time it is customary to let the bud come out somewhat higher and to top to more leaves at first and then to one or two less each subsequent time the field is gone over.

Soon after the plants are topped, suckers will begin to grow from the axils of the leaves. The first suckers will appear at the top of the plant, and so on downward as the upper ones are broken off. Two full sets of suckers will usually grow on a plant, but it will be necessary to go over the field as many as five or six times at intervals of about one week in order to get them all. The whole object of topping will be defeated if these suckers are allowed to grow, and generally they should not be permitted to get more than about 4 inches long before they are removed. Sometimes, however, when a period of wet weather comes just as the tobacco should be getting ripe, it may be of advantage to let the suckers alone temporarily, as their growth will tend to absorb the energies of the plant and prevent the leaves from taking on a second growth, which would make them coarse and dark.

HARVESTING.

When the tobacco is to be harvested by cutting the entire plant, as is customary in the Old Belt, the general condition of the whole plant must be considered, allowing the top leaves to get as ripe as possible without too much offsetting the loss at the bottom of the plant. Generally, a plant will be ripe in from 90 to 100 days after transplanting, and in about 35 or 40 days after topping, but this is subject to great variation, dependent primarily upon seasonal conditions. When the tobacco is to be harvested by priming, or picking the leaves off as they ripen, the harvest begins whenever the bottom leaves demand it, generally in about two or three weeks after topping, or even before topping in some instances. The field subsequently will need to be gone over about once a week until all the

FIG. 6.—A fine field of tobacco nearly ready for harvest in the Old Belt section.

leaves are removed, usually about four or five times in all. Figure 6 shows a fine field of tobacco in the Old Belt section near Winston-Salem, N. C., which is about ready for the harvest, and figure 7 gives a view of a field in the New Belt section near Greenville, N. C., which is in actual process of harvest by the priming method. The more common form of law-wheel truck for hauling out the leaves is shown in figure 8. To cure up sweet and with good color, particularly on the stiffer class of soils of the Old Belt section, the tobacco must be ripe when harvested, but if it is overripe it will be lacking in toughness and luster.

The question of the comparative merits of the priming method as compared with cutting the entire plant is somewhat complicated by local conditions and is a matter of considerable controversy. Theoretically the priming method, whereby each leaf is taken at approxi-

mately its stage of maximum development, should be best. The priming method requires somewhat more labor than the cutting method, and the New Belt section has this labor in better supply,

FIG. 7.—Harvesting tobacco by the priming method. The form of truck shown, with a high body which passes over the tops of the standing plants without damage, is convenient for hauling out the leaves.

owing to the surplus that can be shifted temporarily from the cotton fields. The lighter soils of the New Belt and the consequent greater tendency in many cases for the bottom leaves to waste before the top

FIG. 8.—A common type of low-wheel truck in the New Belt section, in which the tobacco leaves are placed as they are picked.

leaves are ripe perhaps makes the priming method relatively more necessary there than in the Old Belt, where the stiffer soils retard deterioration of the bottom leaves while the top leaves are ripening.

In seasons of normal growth, under the conditions existing in the Old Belt, when all the leaves of the plant mature at approximately the same time, quite likely the crop may be most economically and satisfactorily harvested by cutting the entire plant at one time. But when, as in 1912, a prolonged drought causes the bottom leaves to turn yellow and waste away while the top leaves are still quite green, there can be no question that it is much better to prime off the leaves as they ripen, as was actually done by many growers. If priming had been universally followed in that year, undoubtedly it would have saved many thousands of dollars to the tobacco growers of the Old Belt section. Figures 9 and 10 show characteristic harvesting scenes in the New Belt and Old Belt sections.

FIG. 9.—Tobacco harvest in the New Belt section. Stringing the primed leaves under the shade of a tree.

CURING AND HANDLING.

The expert curer exhibits his skill from the very first, as he begins to harvest the crop. He cuts or primes, having clearly in mind what he expects to accomplish in making the cure. For a uniform curing of good color, a first requisite is that the barn be filled with plants or leaves of uniform ripeness and character.

The first step in curing is to yellow the leaf properly. This takes place while the plant is yet living but is slowly approaching death from starvation, since the food and moisture supply is cut off. To expose too long to the sun and air after cutting, even though actual sunburning does not result, greatly diminishes the vitality of the cells of the leaf and it will not yellow so well. The tobacco should, therefore, be housed without excessive wilting or long exposure to the sun and wind.

As soon as the leaf is dead or dry, further yellowing takes place only very slowly, and if there yet remains any considerable amount of moisture in the leaf a red or brown color will immediately begin to develop. In curing, one should keep well in mind the principle that it is necessary to preserve the life (cell activity) and at least some of the moisture while the leaf is yellowing, and so manage as to have the moisture exhausted by the time it is completely yellow, or, rather, a little before it is fully yellow, as the most satisfactory cures and clearest colors generally follow when the leaf is dried out with some green remaining in it. Tobacco yellows best, especially in the first stages, when the temperature of the barn ranges from about 80° to

FIG. 10.—Harvesting tobacco by the whole-plant method, showing a good type of hauling frame, which should be more generally used.

100° F., but it will continue to yellow in the later stages up to 115° or 120°. As the yellowing proceeds, it is well, toward the later stages, to increase the heat slowly toward these higher temperatures and to begin to dry a little on the yellowest leaves by admitting a little extra ventilation.

In order to obtain the best results in yellowing under varied conditions, it is best to have the barn very tight, so that in the earlier stages of yellowing the desired temperatures may be obtained without exhausting the moisture too rapidly. As the yellowing progresses, however, it is necessary that this moisture be gradually and later rapidly removed; and to accomplish this to the best advantage

it is highly desirable that the barn be so arranged as to be fully and freely ventilated, so that it may be possible to steadily remove the warm, moisture-laden air as it becomes saturated.

In drying out an ordinary 16-foot or 18-foot barn, holding say 500 sticks of cut tobacco, about 5,000 pounds of moisture (water) must be removed. The movement of the air through ventilation is the only means of getting rid of this large amount of moisture. Raising the temperature of the air increases its capacity to absorb moisture and creates a draft, provided means are afforded in the construction of the barn for letting out the air rapidly at the top and for letting it in at the bottom. For the outlet at the top a short lever device at each end of the peak for raising the ridgeboard by means of wires

FIG. 11.—A good type of flue-curing tobacco barn, showing the ridgepole ventilator raised. The mouth of one of the bottom air inlets is seen just under the open door.

reaching to the ground, as shown in figure 11, is a handy and simple arrangement. The slit left open when the ridgeboard is raised should be about 5 inches wide. To admit air at the bottom there is always the door, which can be partially opened at will; but this method gives an excess of air immediately in front of and over the door. For an even distribution of the air in all parts of the barn, sewer pipes, about the 4-inch size, set in the wall at appropriate places, will make a good arrangement for the bottom ventilation. The pipes should be set in the wall close to the ground, but just above it on the outside; they should dip just below the ground on the inside, the openings of the different pipes being, respectively, under and near the end and at the middle of each length of flue, including the returns. Each air pipe should be fitted on the outside with a suitable wooden

stopper, to be closed or opened more or less as the conditions of curing require.

Generally it will be found best to begin to open these ventilators and raise the heat somewhat before the tobacco is fully yellow, so that the moisture will be sufficiently exhausted by that time to prevent reddening or sponging. The draft should not be too strong, especially at first, but it should be sufficient to effectively remove the air before, or at least by the time, it becomes saturated.

In light-bodied tobacco, as grown on the lighter soil types, the yellowing process will generally take about 36 to 48 hours under average conditions; but if the tobacco is very heavy and dark, as frequently occurs on the filler soil types in the western part of the Old Belt section, it may be necessary to consume three or four days in the yellowing process. This will be especially necessary if the soil on which the tobacco was grown was rich in ammoniates or if the tobacco was a little underripe when harvested. Under these circumstances there will be an abnormal quantity of reserve nitrogenous food material in the leaf, and it will be necessary to avoid applying much heat for several days or drying the leaf much, in order that these food materials may be consumed by the life processes of the plants, else the tobacco will be rank smelling, dark, and objectionable rather than sweet and agreeable. This explains why it is such a common practice with those who grow tobacco on the more clayey soils of the western part of the Old Belt to let the tobacco hang in the barn for a day or two before any fire is used at all and then to keep the temperature comparatively low so as to prolong the yellowing period, which in this case is really a ripening or sweetening period as well.

When the yellowing of the leaf is approximately completed, during the later stages of which the temperature has been maintained perhaps at from 110° to 120° F., it is then the custom to move up the temperature quite rapidly, say at the approximate rate of $2\frac{1}{2}$ degrees per hour, to 130° or 135°, and to hold it at that point until the leaf itself is entirely dry throughout the barn, or at least on the bottom poles. It is a general rule of curing that it is not safe to exceed this temperature for any length of time before the leaf is dry, because at about this temperature, or a little above, the cells of the leaves are rapidly killed, and when killed they at once release the moisture they contain, which comes immediately to the surface and results at once, by oxidation, in a blackish discoloration known as scalding. Scalding may occur at a much lower temperature than this when the tobacco is full of sap, in the early stages of the cure. When the leaf is dry throughout the barn the ventilators may be partially or perhaps wholly closed, to save fuel, and the heat gradually moved up at the rate of about 5 degrees per hour to about 175° for the light,

bright types, at which point the heat is maintained until all the stems and stalks are completely killed and dried out and the cure finished. Tobacco will tend to redden slightly at a temperature of 180° or above. In the filler districts in the western part of the Old Belt section the stems and stalks are more commonly killed out at about 200°; and sometimes for the last few hours as much as 225°, or even more, is maintained. These higher temperatures are thought to sweeten the leaf and a reddish, rich-looking "face" is imparted, known as "scorching." These excessively high temperatures, however, while still extensively used, may make the leaf more or less brittle, which renders it objectionable for chewing purposes.

After the cure is finished, the tobacco ordinarly should not be allowed to come in high order for any length of time, especially in warm weather, or reddening and perhaps worse damage from mold or decay may result. On the other hand, to keep the tobacco for some time in moderate warmth and moisture may be an advantage in eliminating any remaining green color.[1]

In the South Carolina portion of the New Belt a large proportion of the tobacco is generally sold as soon as it is cured, without either assorting or tying the leaves into hands. Of course, the system of priming the leaves as they ripen makes for an approximate grading, since the leaves taken off at any one time would be from approximately the same portion of the different plants, representing the bottom, middle, or top leaves, as the case might be. When sold in that way the tobacco is allowed to come in soft order as soon as possible (generally in a day or two) after the cure is finished. The leaves are removed from the strings and packed into the wagon body as straight as possible, and the load is immediately taken to the warehouse and sold. In other sections, however, the tobacco is more generally first bulked in the packing house on the sticks as it comes from the curing barn, either in the shingle bulk, as is more customary in the New Belt section, or in the square coop, as is more common in the Old Belt section; or it may be hung up in the packing house or curing barn, the sticks being crowded closely together to keep the leaf from coming into too high order, which would cause it to turn red. The tobacco is then graded and tied into hands at any time convenient to the grower and sold as desired.

Except in cool, very dry weather, tobacco will generally come into order so that it can be removed from the curing barn on about the second morning after the cure is finished. All the doors and ventilators should be opened at night to let in the moist air. The web of the leaf will generally become fairly soft the first night. The next day the barn should be tightly closed if the weather is dry, in order to retain the moisture. At night the barn again should be opened

[1] For more detailed information in regard to the process of curing tobacco, see Farmers' Bulletin 523, entitled "Tobacco Curing."

fully. The stems generally will become soft enough during the second night so that the tobacco can be removed and bulked or rehung in the storage or packing house without breaking.

In softening tobacco for stripping and assorting, an ordering cellar is a great convenience. The cellar generally is dug under the packing-house floor to a depth of 6 or 7 feet, and should be large enough to hold at least a curing of tobacco. The cellar is fitted with light framework on which to hang the sticks of tobacco. Care must be taken to locate the cellar where there is sufficient clay in the subsoil so the walls will stand firm, and it must be situated so that

FIG. 12.—A good type of tobacco storage and stripping house, with an ordering cellar under the building.

water will not rise or flow into it. It should be banked around the outside to keep out surface water, and it would be safest to put a drainpipe in the bottom to carry off seepage water. At least one small glass window also should be provided.

The stripping room is usually built as a shed on one side of the packing house, into which the ordering cellar opens by a door and steps. The best light, free from glare for stripping, will be obtained if the windows are mostly on the north side of the stripping room. A well-appointed storage house, ordering cellar, and stripping room is shown in figure 12. The cellar is under the main building, and the stripping room is in the shed to the right.

One thing which the tobacco grower must constantly have in mind while the tobacco is in bulk or storage is the danger of damage by mold, especially during protracted periods of warm, moist weather.

In assorting tobacco as it is stripped from the stalk, which is the common practice in the Old Belt, about four fundamental grades generally will be obtained from a given plant. There will be the trashy lugs, clean lugs, leaf, and tips as they are taken from the bottom and then on to the top of the plant. In the actual assorting of an entire curing a number of other secondary grades will be made, sometimes as many as 8 or 10 in all, based upon differences in color, texture, and body. A great number of grades are recognized by the trade as wrappers, cutters, export leaf, fillers, smokers, etc., and each of these is subdivided into a number of subgrades, but, of course, only a few of them would appear in any single crop or curing. The better grades of lugs and the leaf are tied into comparatively small hands of about 10 or 15 leaves each, but the poorer lug grades are generally tied into larger hands of 20 to 40 leaves each. The hands or bundles are tied with a leaf, which is folded for this purpose by turning both edges backward and inward so as to form a neat band. This is then deftly given a couple of turns tightly around and partially or completely covering the butts of the leaves forming the bundle, beginning with the tip of the tie leaf. The butt end of the tie is tucked through the hand between the leaves so as to wedge and hold the tie leaf in place.

Before placing tobacco on the market, it should be brought into good but not too high order, and its appearance will be improved if it is bulked down either on or off the sticks for a day or two. In most sections of the flue-cured district the farmer can dispose of his tobacco either by direct sale on the warehouse floor or through the grower's pooling organization. If sold on the warehouse floor, care should be taken to avoid a glutted market, for at such time the prices are generally somewhat reduced because the buyers can not handle and take care of it as fast as it comes in.

The entire cost of producing and marketing flue-cured tobacco is estimated at 6 to 10 cents a pound, according to conditions.

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Contribution from the Bureau of Chemistry, Carl L. Alsberg, Chief.

November 5, 1913.

THE REFRIGERATION OF DRESSED POULTRY IN TRANSIT.

By M. E. Pennington, *Chief, Food Research Laboratory*, and A. D. Greenlee, *Assistant Chemist;* H. C. Pierce, E. Witmer, H. A. McAleer, and M. K. Jenkins, *in the field;* J. S. Hepburn, M. O. Stafford, H. C. Robertson, and E. L. Connolly, *in the laboratory.*

HISTORICAL SKETCH.

Considering the great commercial importance of the transportation of perishable products under refrigeration, very little systematic work has been done on the subject. The Transactions of the First International Congress of Refrigeration, held in Paris in 1908, have brought together a mass of diverse information which has been supplemented by the reports presented at the Second Congress of Refrigeration, at Vienna, in 1910. Yet the underlying principles of successful transportation under refrigeration, namely, the temperatures obtainable and their exact effect on the condition of the produce when it reaches the market, is but scantily treated. The very excellent report of J. M. Culp before the International Railway Congress, at Berne, Switzerland, in 1910, gives the history of refrigerated carriers in the United States, and much of technical and general interest as well. Horr [1] has presented some general facts regarding the transportation of poultry, butter, and eggs from the viewpoint of the dairy freight agent, but he gives nothing specific concerning car construction, temperatures maintained, or the effect of the haul on the condition of the goods.

The most definite information on this subject is given in the report by Powell and his associates [2] on the transportation of citrus fruits. This investigation shows that it requires several days for the iced refrigerator car to remove the heat from the load of wrapped, boxed oranges, and that precooled fruit maintains a more constant temperature during the haul than can be obtained when the fruit is loaded unchilled. Very decided differences in temperature were noted in the various parts of the car, especially between the top and bottom of the load, and in the air of the car as compared with the

[1] First International Congress of Refrigeration. Transactions, Paris, 1908.

[2] U. S. Dept. Agr., Bureau of Plant Industry Bul. 123.

fruit in the boxes. The temperature of the car followed the atmospheric fluctuations to a slight degree, while the fruit was frequently unaffected by a car temperature that rose or fell 5 degrees, provided the increased or decreased temperature was not continuous. The present investigation, which includes corresponding data for products requiring lower temperatures than do citrus fruits, confirms and amplifies this information. Powell fixed the fundamentals of the transportation of refrigerated citrus fruits, which do not require a temperature of less than 40° F., and if well handled survive at higher temperatures. He also demonstrated that while the use of low temperatures during transit might enable mechanically injured fruit to reach the market in a salable condition, such fruit would not stand the vicissitudes of marketing and would ultimately redound to the disadvantage of the industries involved, as do all poor products that reach the consumer. In this conclusion, also, the writers of the present bulletin concur, and would lay even more emphasis than does Powell on the bad results seen during the marketing of poultry transported at fluctuating or excessively high temperatures.

Decay in oranges, as well as in almost all other fruits, is definite, and can be gauged with accuracy by inspection; not so with meats, fish, dressed poultry, or eggs. Deterioration, the gradations of which in these products are almost infinite, is so obscure that a description of the appearance alone does not afford an accurate method of fixing the point to which it has progressed. If an exact statement of condition is desired, the laboratory must be depended upon for the composition, since it is the variation between the composition at the time of killing and at the time of observation that measures the changes occurring in the interim. In the course of certain investigations conducted in the Food Research Laboratory it has been found necessary to determine by chemical analysis the effect of temperature upon the speed of decomposition of dressed poultry. A summary of a large number of analyses of chicken flesh from dressed birds kept at varying temperatures[1] showed in a striking fashion the relative rate of decomposition when all the factors except the temperature were constant. The analyses include a study of the distribution of protein and nonprotein nitrogen, the latter increasing at the expense of the former as decomposition proceeds.

Since the amount of nonprotein nitrogenous material is especially indicative of deteriorative changes, an estimation of its quantity in a flesh of known normal composition gives a ready means of measuring the change that has occurred. A method[2] sufficiently rapid and accu-

[1] Hearings before the Committee on Manufactures, United States Senate, Sixty-second Congress, May, 1911.

[2] An Application of the Folin Method to the Determination of Ammoniacal Nitrogen in Meat. J. Amer. Chem. Soc., 1910, *32*: 561.

rate for practical purposes has been devised and used to determine the amount of ammoniacal nitrogen in chicken flesh prepared for market in different ways.[1] Therefore, when the changes occurring in flesh during transportation were to be determined, the investigators had a very satisfactory laboratory method at hand by which to obtain the information sought. At the end of the railroad haul, and again at each change of environment during marketing, samples of the product were subjected to an analysis to determine the quantity of ammoniacal nitrogen present. It is upon these laboratory findings, supplemented by the usual visual market inspection, that the statements of condition given in this report are based. It has been found, also, that the development of acidity in the fat is an index of the rate of decay, being especially valuable as an indicator of the promptness and efficiency of the removal of the animal heat.[2] Accordingly, the amount of acid in the gizzard fat was determined for all shipments before they left the packing house.

From the previous work in the laboratory the methods for determining the state of preservation of dressed poultry are fairly well defined. These methods furnish a uniform means of determining the effect of changes in temperature on the keeping of the poultry. They, therefore, may be made the basis of a study of the relation of the temperatures in different parts of a refrigerator car to the changes that occur in dressed poultry while in transit and after arrival at the market. The results obtained furnish a definite means of testing the efficiency of refrigerator cars.

PURPOSE OF THE INVESTIGATION.

The purpose of this investigation has been to determine the temperatures prevailing in refrigerator cars hauling dressed poultry throughout the entire transportation period, and to observe the effect of such temperatures on the condition of the poultry when it arrives at the market. Records were kept of its condition during the whole period of marketing. The responsibility to be assigned to the packer, the carrier, the wholesaler, and the retailer has been apportioned in accordance with the history of the environment and the findings of the chemical laboratory, to which all samples have been submitted for analysis. The details of the effect of the preparation for market and of the treatment during marketing on the product which finally reaches the consumer are reserved for another publication, except in so far as they are needed to elucidate the part played by the carrier.

While gathering the data necessary to answer the primary question of the investigation, namely, the temperatures maintained by cars

[1] U. S. Dept. Agr., Bureau of Chemistry Cir. 70.

[2] Pennington and Hepburn. J. Amer. Chem. Soc., 1910, *32:* 568.

transporting perishable foodstuffs requiring more refrigeration than is needed for fruit, much that is of interest to the packer, the carrier, the middleman, and the consumer has been unearthed. It was observed, for example, that different lots of poultry having identical treatment before shipment, and approximately the same atmospheric conditions during the haul, and requiring the same amount of time to reach the market, arrived in widely varying states of preservation. The differences were attributable, apparently, to the type of car in which the journey was made. A study of the construction of the cars in use on different lines revealed a marked variation both in materials and in construction. Accordingly, those factors in car construction on which efficiency of refrigeration depends were studied, and the temperatures observed in the cars correlated, not only with the preservation of the produce but with the construction of the car as well. As was to be expected from previous work, the temperature of the air in the different parts of the car was found to vary within sufficiently wide limits to affect the stability of the flesh of the poultry. For example, that next to the side walls was quite unlike that in the middle of the car. It was deemed advisable to obtain accurate data on such variations, as well as on the fluctuations in the temperature of the air in the car, compared with the temperature changes undergone by the poultry inside the packages.

SCOPE OF THE INVESTIGATION.

The experiments herein reported, covering the period between August, 1909, and October, 1912, include 120 car-lot shipments of dressed poultry and aggregate 140,000 miles of haul. The hauls averaged between 1,000 and 1,500 miles, terminating almost invariably in New York City. No car was used twice, and six different car lines are represented. The weather conditions varied, because the work continued from season to season, and the territory involved extended from western Iowa to central Tennessee.

The treatment which the produce received before shipment was commercial, but represented the best methods in use. The cars were those ordinarily received by the packer and in no case was a special car used, nor was any difference made in the handling of the car en route because it was under observation. Indeed, the railroads in most instances did not know that the work was being done until after it was finished. The information obtained at the market center covered the usual routine of the unloading of the car, the holding of the goods by the wholesaler for a short period, and its further detention by the retailer. In all of this part of the work commercial surroundings and commercial routine prevailed; hence the facts which follow may be accepted as indicative of the results of the practices of that portion of the trade equipped to handle dressed poultry in car lots or in smaller quantities.

SHIPMENT OF POULTRY.

PREPARATION.

The dressed poultry used in this investigation was prepared for shipment in modern poultry packing houses equipped with mechanical refrigeration. The birds varied in size, some being broilers, some roasters, and some fowls or stewing chickens. Killing was done by cutting the jugular vein in order to drain the carcass of blood, then puncturing the brain to paralyze the feather muscles and destroy life.

The poultry was dry picked according to the usual commercial methods, special care being taken to select only those birds with sound skins to obviate the nonuniformity which might be introduced by torn and rubbed skins. Immediately after dressing, the birds were placed in chill rooms cooled by means of mechanical refrigeration to 32° F. (0° C.), where they were held for 24 hours to remove all of the animal heat. A thermograph registered the temperature changes during chilling. The birds, chilled to 32° F. (0° C.) or less throughout, were then packed in boxes, one dozen to the box. The packing was done in a chilled room, where the boxes remained until they were loaded into the refrigerator car with the usual commercial carload shipment of dressed poultry.

LOADING.

The cars were iced 24 hours before loading, the percentage of salt added varying from 5 to 15 per cent, depending upon the weather. The temperature of the car midway between the door and the end was recorded at that time and again when the loading was finished and the car closed. Records were also kept of prevailing atmospheric conditions. Thermographs, or self-registering thermometers, which made a complete record of the temperature during the entire transit period, were placed in the car, one near the floor next to the bunker to record the air temperature in the coldest part of the car, and another at the top of the load near the center of the car to furnish a similar record for the warmest part of the car, that is, warmest in warm weather, but, on account of loose doors and poor insulation, perhaps not as warm as some other parts of the car in extremely cold weather. The boxes of poultry to be examined chemically were in juxtaposition to one of these thermographs. The period of transit varied from 5 to 10 days and in almost every case was concluded in New York City.

CHEMICAL ANALYSIS.

When the car was opened for unloading, a sample from three fowls was selected from the experimental packages and subjected to the laboratory examination. This consisted in estimating the amount of ammoniacal nitrogen [1] in the muscle tissue, which is an index of

[1] Pennington and Greenlee. An application of the Folin method to the determination of ammoniacal nitrogen in meat. J. Amer. Chem. Soc., 1910, *32* (4): 561.

the progress of flesh changes, and also the amount of free acid [1] in the fat, since the rise in acidity is an indication of the aging of the whole carcass. The results of the chemical analyses and the condition on arrival at destination of 78 such experiments which are comparable in their methods of procedure are shown in Table 1.

TABLE 1.—*The transportation of dry-packed dressed poultry in refrigerator cars.*

Experiment No.	Shipment made from—	Date of killing.	Record of chilling.			Record of transportation.					At the market.				
			Time (days).	Maximum and minimum temperature of chill room.	Temperature of body cavity when packed.	Temperature of car.		Time (days).	Thermometer record.	Temperature of body cavity at end of journey.	Date of arrival at New York City.	Time since killing (days).	Ammoniacal nitrogen.		Acid value of crude gizzard fat.
						Before loading.	After loading.						Fresh basis.	Dry basis.	
		1910.		°F.	°F.	°F.	°F. Center.		°F.	°F.	1910.		P. ct.	P. ct.	
2001	Iowa	Sept. 6	1	26 to 33	30	57	73	6	32 to 37	....	Sept. 13	7	0.0147	.....	2.13
2003	...do...	Sept. 13	1	28 to 36	34	32	50	6	34 to 36	....	Sept. 20	7	.0132	.....	2.13
2004	...do...	Sept. 20	1	27 to 33	34	40	65	7	30 to 37	37	Sept. 28	8	.0118	.....	2.21
2006	...do...	Sept. 27	1	23 to 32	33	35	55	7	30 to 33	37	Oct. 5	8	.....	.....	3.95
						Top.									
2008	...do...	Oct. 4	1	28 to 34	36	40	50	7	31 to 33	36	Oct. 12	8	.0115	.....	1.76
2010	...do...	Oct. 10	1	29 to 37	35	50	58	7	31 to 34	36	Oct. 18	8	.....	.....	2.88
2012	...do...	Oct. 11	1	30 to 43	34	36	60	6	34 to 36	36	Oct. 18	7	.0129	.....	1.63
2015	...do...	Oct. 17	1	27 to 32	41	50	58	8	26 to 30	34	Oct. 26	9	.0140	.....	3.03
2017	...do...	Oct. 18	1	24 to 32	30	39	40	7	27 to 29	34	Oct. 26	8	.0127	.....	1.94
2018	...do...	Oct. 24	1	31 to 35	36	48	50	8	29 to 35	41	Nov. 2	9	.0123	.....	2.43
2019	...do...	Oct. 25	2	28 to 30	34	32	34	6	.....	32	Nov. 2	8	.0122	.....	1.90
2020	...do...	Nov. 1	1	30 to 36	34	39	43	8	26 to 31	34	Nov. 10	9	.0122	.....	2.10
2022	...do...	Nov. 8	1	27 to 37	32	32	36	7	25 to 32	37	Nov. 16	8	.0140	.....	3.31
2024	...do...	Nov. 16	1	27 to 33	30	36	36	7	19 to 25	36	Nov. 24	8	.0129	0.0512	2.31
2025	...do...	Nov. 22	1	29 to 40	34	34	37	6	24 to 32	36	Nov. 29	7	.0137	.0545	1.41
2026	...do...	Nov. 26	1	17 to 28	39	30	30	8	10 to 22	34	Dec. 5	9	.0123	.0492	2.89
2027	...do...	Nov. 29	1	20 to 31	32	30	30	7	23 to 25	30	Dec. 7	8	.0137	.0538	1.87
2028	...do...	Dec. 6	1	24 to 32	30	32	30	7	22 to 24	34	Dec. 14	8	.0120	.0474	2.06
2029	...do...	Dec. 9	3	28 to 41	32	32	30	10	19 to 28	30	Dec. 22	13	.....	.0572	2.30
2030	...do...	Dec. 10	1	29 to 35	32	30	25	8	22 to 37	30	Dec. 19	9	.....	.0564	3.08
											1911.				
2031	...do...	Dec. 23	1	30 to 35	32	30	28	10	25 to 38	30	Jan. 3	11	.0139	.0541	2.17
2032	...do...	Dec. 30	1	32 to 35	28	32	32	11	20 to 37	30	Jan. 11	12	.0158	.0616	2.88
		1911.													
2033	...do...	Jan. 3	1	26 to 37	32	27	28	8	24 to 26	35	Jan. 12	9	.....	.0594	1.81
2034	...do...	Jan. 20	1	35 to 39	34	30	30	7	24 to 26	40	Jan. 28	8	.0132	.0496	1.28
2035	...do...	Jan. 24	1	31 to 34	41	38	40	7	25 to 30	34	Feb. 1	8	.0134	.0482	1.12
2036	...do...	Jan. 30	1	30 to 36	36	36	38	7	28 to 34	31	Feb. 7	8	.0129	.0506	1.87
2037	...do...	Feb. 1	2	33 to 37	30	30	26	7	31 to 37	34	Feb. 10	9	.0140	.0519	1.54
2038	Tennessee.	Mar. 9	1	28 to 35	30	39	59	5	28 to 34	36	Mar. 15	6	.0106	.0396	.95
2039	...do...	Mar. 13	2	26 to 39	26	28	36	6	27 to 29	36	Mar. 21	8	.0125	.0449	1.25
2040	...do...	Mar. 15	2	28 to 45	28	21	26	5	28 to 30	34	Mar. 22	7	.0102	.0387	.91
2041	...do...	Mar. 21	2	24 to 36	30	29	35	6	28 to 31	32	Mar. 29	8	.0120	.0451	1.06
2042	...do...	Mar. 28	2	30 to 34	30	31	35	6	28 to 35	34	Apr. 5	8	.0129	.0513	1.45
2044	...do...	Apr. 12	2	26 to 38	32	41	48	6	26 to 37	....	Apr. 20	8	.0126	.0498	1.08
2046	...do...	Apr. 19	2	27 to 42	32	33	47	6	28 to 35	35	Apr. 27	8	.0126	.0488	1.44
2048	...do...	Apr. 26	2	28 to 50	37	34	44	6	32 to 41	37	May 4	8	.0132	.....	1.80
2050	...do...	May 3	2	27 to 38	28	36	46	6	35 to 47	42	May 11	8	.0149	.0568	1.36
2053	...do...	May 16	2	36 to 50	33	37	52	6	.....	46	May 24	8	.0188	.0760	3.76
2054	...do...	May 23	1	31 to 40	32	34	44	7	32 to 42	42	May 31	8	.0146	.0564	1.59
2055	...do...	May 30	1	37 to 40	26	35	52	6	25 to 34	(2)	June 6	7	.0127	.0497	1.06
2056	...do...	June 15	1	31 to 42	31	37	52	6	34 to 42	35	June 22	7	.0146	.0564	1.27
2057	...do...	June 27	4	24 to 36	33	36	56	5	20 to 28	35	July 6	9	.0110	.0437	2.03
2059	...do...	July 6	1	30 to 42	30	43	50	5	27 to 44	40	July 12	6	.0154	.0610	1.38
2060	...do...	July 13	1	26 to 41	31	37	52	6	36 to 44	41	July 20	7	.0140	.0533	1.08

[1] Pennington and Hepburn. The determination of the acid value of crude fat and its application in the detection of aged foods. J. Amer. Chem. Soc., 1910, *32* (4): 568.

[2] Hard frozen.

TABLE 1.—*The transportation of dry-packed dressed poultry in refrigerator cars*—Contd.

Experiment No.	Shipment made from—	Date of killing.	Record of chilling. Time (days).	Record of chilling. Maximum and minimum temperature of chill room.	Record of chilling. Temperature of body cavity when packed.	Record of transportation. Temperature of car. Before loading.	Record of transportation. Temperature of car. After loading.	Record of transportation. Time (days).	Record of transportation. Thermometer record.	Record of transportation. Temperature of body cavity at end of journey.	At the market. Date of arrival at New York City.	At the market. Time since killing (days).	At the market. Ammoniacal nitrogen. Fresh basis.	At the market. Ammoniacal nitrogen. Dry basis.	At the market. Acid value of crude gizard fat.
		1911.		°F.	°F.	°F.	°F.		°F.	°F.	1911.		P. ct.	P. ct.	
2062	Tennessee.	Aug. 30	2	26 to 35	30	34	42	6	35 to 43	39	Sept. 7	8	.....	.....	1.45
2063	...do...	Sept. 6	2	34 to 38	....	42	47	6	34 to 43	35	Sept. 14	8	.0102	.0418	3.20
2064	...do...	Sept. 14	1	32 to 39	36	41	54	6	30 to 36	40	Sept. 21	7	.0110	.0465	2.84
2065	...do...	Sept. 21	2	35 to 40	30	37	41	5	33 to 40	39	Sept. 28	7	.0140	.0560	1.82
2066	...do...	Sept. 26	3	29 to 38	32	39	52	6	26 to 37	35	Oct. 5	9	.0126	.0519	2.61
2067	...do...	Oct. 4	2	34 to 38	32	35	46	6	.....	32	Oct. 12	8	.....	.0639	3.08
2068	...do...	Oct. 23	1	31 to 38	30	28	38	6	14 to 19	30	Oct. 30	7	.0112	.0460	2.48
2069	...do...	Nov. 2	1	27 to 34	32	36	40	5	19 to 30	30	Nov. 8	6	.0123	.0483	2.22
2070	...do...	Nov. 8	2	27 to 36	28	31	45	6	28 to 39	29	Nov. 16	8	.0129	.0516	2.10
2071	...do...	Nov. 20	1	27 to 34	32	38	38	8	35 to 47	44	Nov. 29	9	.0148	.0568	3.10
2072	...do...	Dec. 1	4	22 to 35	28	35	41	6	20 to 28	33	Dec. 11	10	.....	.....	4.46
2073	...do...	Dec. 7	5	22 to 35	....	44	44	6	25 to 38	28	Dec. 18	11	.....	.....	1.82
2074	...do...	Dec. 19	1	23 to 29	35	.....	.....	6	21 to 33	36	Dec. 26	7	.0125	.0502	1.66
		1912.									1912.				
2075	...do...	Mar. 26	2	30 to 34	29	38	38	6	25 to 32	33	Apr. 3	8	.0118	.....	1.05
2076	...do...	Mar. 28	1	.....	30	40	48	5	35 to 44	38	Apr. 3	6	.0087	.....	.85
2077	...do...	Apr. 12	1	28 to 33	33	41	52	5	28 to 35	39	Apr. 18	6	.0141	.....	1.24
2078	...do...	Apr. 16	1	24 to 32	31	34	48	6	24 to 29	30	Apr. 23	7	.0115	.....	1.07
2079	...do...	Apr. 18	1	20 to 33	31.5	.....	.....	5	23 to 34	33	Apr. 24	6	.0112	.....	.99
2080	...do...	Apr. 24	2	25 to 33	31	36	48	5	26 to 32	35	May 1	7	.0106	.....	1.58
2081	...do...	Apr. 26	4	26 to 36	30.5	36	48	6	27 to 38	37	May 6	10	.0105	.....	2.37
2082	...do...	Apr. 30	1	27 to 34	32	31	40	5	34 to 37	42	May 6	6	.0109	.....	1.53
2083	...do...	May 3	1	30 to 34	32	36	46	6	27 to 36	30	May 10	7	.0132	.....	1.76
2084	...do...	May 13	1	30 to 34	31	30	44	7	21 to 45	29	May 21	8	.0140	.....	1.48
2085	...do...	May 24	1	33 to 36	32	38	50	6	24 to 34	38	May 31	7	.0123	.....	2.23
2086	...do...	June 11	1	29 to 34	29	34	54	6	30 to 36	29	June 18	7	.0118	.....	1.08
2087	...do...	June 13	6	25 to 37	32	39	50	6	31 to 36	45	June 25	12	.0137	.....	2.12
2088	...do...	July 1	1	25 to 36	30	40	56	7	28 to 34	42	July 9	8	.0132	.....	1.71
2089	...do...	July 8	3	26 to 39	35	35	50	5	26 to 30	36	July 16	8	.0126	.....	3.34
2090	...do...	July 25	1	28 to 36	30	40	60	6	30 to 36	43	Aug. 1	7	.0132	.....	1.92
2091	...do...	July 30	3	28 to 33	30	40	58	6	28 to 34	42	Aug. 8	9	.0130	.....	2.35
2093	...do...	Aug. 29	1	28 to 33	33	36	46	5	24 to 33	39	Sept. 4	6	.0120	.....	3.27
2094	...do...	Sept. 18	2	27 to 33	31	33	48	6	19 to 32	30	Sept. 26	8	.0119	.....	3.23
2096	...do...	Sept. 26	1	28 to 33	31	31	47	5	20 to 27	29	Oct. 2	6	.0118	.....	1.51
2097	...do...	Oct. 4	0	26 to 30	30	33	53	5	.....	34	Oct. 9	5	.0127	.....	1.69
2099	...do...	Oct. 17	1	28 to 30	31	31	48	6	22 to 31	34	Oct. 24	7	.0112	.....	1.22

GRAPHIC REPRESENTATION OF FOUR TYPICAL SHIPMENTS.

Table 1 shows that there is a decided variation in the different factors which influence the keeping of dressed poultry during transportation, even when proper methods of commercial procedures are followed. It will be observed that the amount of change occurring during the haul varies, and that, generally speaking, the higher the temperature of the carrier the greater the decomposition. To convey clearly the effect of differences in temperature during the haul and while on the market, four typical shipments, taken from Table 1, are shown graphically in figure 1. The rectangular bars indicate the relative deterioration, the solid bars standing for comparatively high-temperature shipments and the frame bars for comparatively low-temperature shipments. The lines on the chart are the temperature

records for the different periods indicated at the bottom of the chart. The figures at the side of the chart are degrees Fahrenheit. The periods of day and night are indicated at the bottom of the chart as solid or open rectangles.

Shipment No. 2003 is an example of a shipment made under conditions that would have been satisfactory for citrus fruit. This shipment left the packing house in western Iowa on September 13, 1910. The haul occupied 6 days, during which time the temperature in the car increased from 32° to 36° F. (0° to 2.2° C.), most of this rise

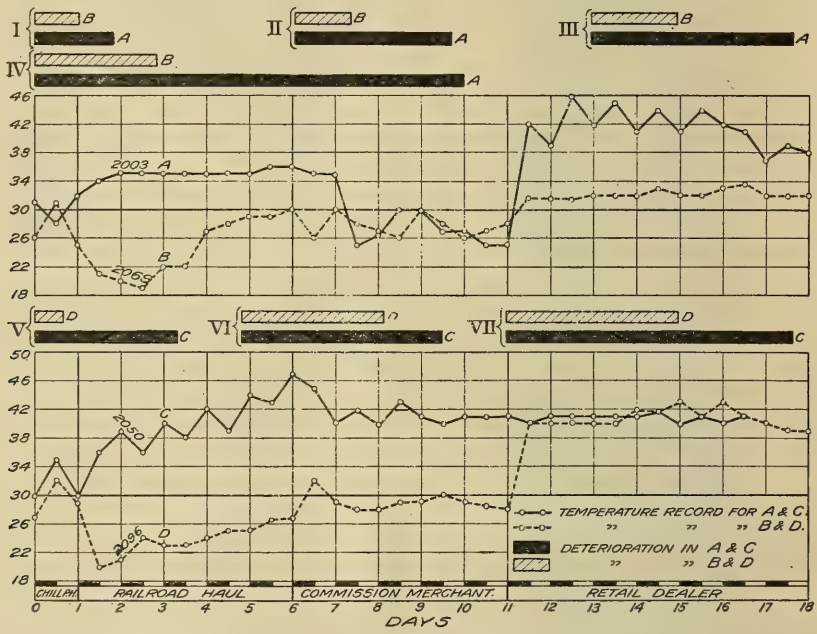

FIG. 1.—Deterioration as shown by ammoniacal nitrogen content of high-temperature and low-temperature shipments; and market temperature records.

Two shipments held at similar temperatures in commission house: No. 2003, A=high-temperature shipment; No. 2069, B=low-temperature shipment. Condition based on analyses: I, At end of railroad haul; II, at end of period at commission house; III, after 4 days at retail store; IV, after 7 days at retail store.

Two shipments held at similar temperatures in retail store: No. 2050, C=high-temperature shipment; No. 2096, D=low-temperature shipment. Condition based on analyses: V, At end of railroad haul; VI, after 4 days at retail store; VII, after 7 days at retail store.

occurring during the first 24 hours. Experiment No. 2069 is a shipment wherein the temperatures during the haul averaged 10 degrees lower. This shipment, which originated in Tennessee, left for New York on November 2, 1911. The haul occupied 5 days, the maximum temperature, which was 30° F. (−1.1° C.), being reached on the day of arrival. The minimum temperature was 19° F. (−7.2° C.), reached about 36 hours after the haul began.

The respective temperature records of these two shipments and a graphic representation of the increase in ammoniacal nitrogen are shown as A and B in figure 1. To make the differences readily observ-

able the two records are parallel on the same chart. The temperature in the packing-house chillroom from which the birds were loaded into the car was nearly the same for both shipments. Here, however, the similarity ceases. During the railroad haul there was a decided difference, especially for the first three days. The relative condition, as determined by analysis at the end of the transit period, is represented by Graph I of figure 1. The amount of change during the haul, where 32° to 36° F. (0° to 2.2° C.) prevailed, is about twice as much as occurred when the temperature was between 19° and 30° F. (−7.2° to −1.1° C.). In the commission man's chillroom the samples were subjected to similar temperatures, but at the end of this period the quality difference is even more pronounced, as seen in Graph II. In this case the impetus given to decay by the higher temperature during the haul could not be checked by subsequent low temperatures. At the retail store shipment No. 2003 was at a great disadvantage as compared with No. 2069, and here the deterioration in the high-temperature shipment was very rapid. The relative deterioration during the first four days is shown in Graph III, that during the subsequent three days in Graph IV.

The transportation temperatures for No. 2050 and No. 2096 differed more than did those for the two previous experiments, and the chemical results were correspondingly different (Graph V). Of the low-temperature shipments, No. 2096 was on the average colder than No. 2069 and its ammoniacal nitrogen is lower. No. 2050 was hauled at a higher temperature than No. 2003 and the nitrogen is also higher (compare Graphs I and V). The temperatures in the commission house for experiments Nos. 2050 and 2096 approximated the temperatures in their respective cars. At the retail shop the temperature records again converge. After four days in the retailer's ice box, where the temperatures fluctuated from 40° to 43° F. (4.4° to 6.1° C.), the relative rate of decomposition, represented in Graph VII, indicates that the impetus given the deteriorative changes in No. 2050 during transportation at high temperatures is still in evidence, and their effect is not lost after the last three days at the retail store, during which the high-temperature shipment gains on its own former rate of change. In the retail shop, experiments Nos. 2050 and 2096 were held at very similar temperatures, fluctuating from 40° to 43° F. (4.4° to 6.1° C.), and this warm environment shows its deteriorating effect on both the high and low temperature shipments (Graphs VI and VII, fig. 1).

AVERAGE RESULTS OF LOW AND HIGH TEMPERATURE SHIPMENTS.

In order to obtain a number of observations, such as are cited for these four individual shipments, the chemical analyses in Table 1 were divided into four groups: First, those in which the record of the

thermograph, which was next to the experimental box of poultry, showed an average temperature of 18° to 26° F. (−7.8° to −3.3° C.); second, those which showed an average temperature of 27° to 30° F. (−2.8° to −1.1° C.); third, those at 31° to 34° F. (−0.5° to 1.1° C.); and fourth, those at 35° to 39° F. (1.7° to 3.9° C.). None of the experiments showed an average temperature of over 39° F. (3.9° C.). The temperature during portions of the haul have exceeded these group limits, but the average temperature for the entire period of

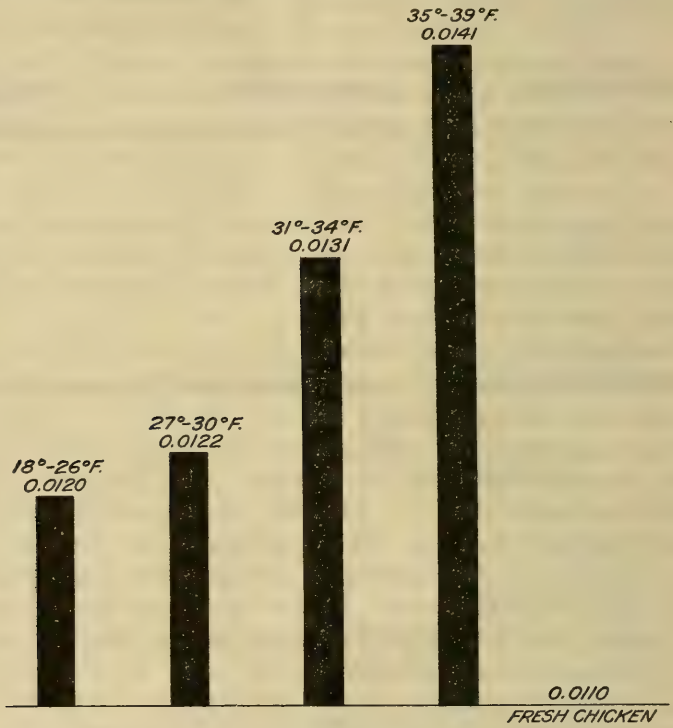

FIG. 2.—Deterioration during haul as affected by car temperatures, as shown by the percentage of ammoniacal nitrogen.

transportation lay between the maximum and minimum limits as given for the group. These groups are shown in Table 2 and the results are represented graphically in figure 2.

Fresh chickens contain about 0.0110 per cent of ammoniacal nitrogen. Amounts distinctly in excess of this figure may be taken as an indication of deterioration, especially when obtained by average, hence it is made the base line of the chart.

When the car temperatures averaged from 18° to 26° F. (−7.8° to −3.3° C.) the deterioration was very slight, the ammoniacal nitrogen having increased to only 0.0120 per cent; but when the car temperatures were from 35° to 39° F. (1.7° to 3.9° C.) the ammoniacal nitrogen had increased to 0.0141 per cent, a deterioration of three times that

at the lowest temperature. This difference in composition at the end of the railroad haul continues with increasing magnitude throughout the period at the wholesale commission house and at the retailer's. (See Table 3.)

TABLE 2.—*Content of ammoniacal nitrogen in flesh of chickens after railroad haul.*

Group 1—18° to 26° F.			Group 2—27° to 30° F.			Group 3—31° to 34° F.			Group 4—35° to 39° F.		
Experiment No.	Car line.	Ammoniacal nitrogen.	Experiment No.	Car line.	Ammoniacal nitrogen.	Experiment No.	Car line.	Ammoniacal nitrogen.	Experiment No.	Car line.	Ammoniacal nitrogen.
		Per cent.			*Per cent.*			*Per cent.*			*Per cent.*
2024	A	0.0129	2017	D	0.0127	2001	D	0.0147	2003	D	0.0132
2026	A	.0123	2018	A	.0123	2004	D	.0123	2048	B	.0132
2028	D	.0120	2020	D	.0122	2006	D	.0144	2050	B	.0149
2030	E	.0120	2025	D	.0122	2008	D	.0134	2054	B	.0146
2068	D	.0112	2031	D	.0139	2012	D	.0129	2056	B	.0146
2069	D	.0123	2035	D	.0134	2044	B	.0126	2060	B	.0140
2074	D	.0125	2036	D	.0129	2046	B	.0126	2065	B	.0140
2078	D	.0115	2038	B	.0106	2066	E	.0126	2071	C	.0148
2094	C	.0119	2039	B	.0125	2077	D	.0141	2084	B	.0140
2096	C	.0118	2040	B	.0102	2083	B	.0132			
			2041	B	.0120	2086	D	.0118			
			2042	B	.0129	2087	D	.0137			
			2055	B	.0127	2088	D	.0132			
			2075	D	.0118	2090	D	.0132			
			2079	C	.0112	2091	D	.0130			
			2080	D	.0106						
			2085	C	.0123						
			2089	D	.0126						
			2093	C	.0123						
			2099	C	.0119						
Average.		.0120			.0122			.0132			.0141

TABLE 3.—*Content of ammoniacal nitrogen in flesh of chickens during marketing period after subjection to extreme low temperatures and extreme high temperatures during railroad haul.*

Date of shipment.	Experiment No.	Content of ammoniacal nitrogen.			
		Transportation sample.	Commission house sample.	First sample from retailer.	Second sample from retailer.
Low-temperature shipments, 18° to 26° F. (−7.8° to −3.3° C.):		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Nov. 16, 1910	2024	0.0129	0.0132	0.0144	0.0160
Nov. 26, 1910	2026	.0123	.0139	.0147	.0154
Dec. 6, 1910	2028	.0120	.0136	.0146	.0160
Oct. 23, 1911	2068	.0112	.0112	.0140	.0144
Nov. 2, 1911	2069	.0123	.0126	.0134	.0144
Dec. 19, 1911	2074	.0125	.0106	.0139	.0174
Apr. 16, 1912	2078	.0115	.0126	.0132	.0150
Sept. 18, 1912	2094	.0119	.0142	.0168	.0181
Sept. 26, 1912	2096	.0118		.0150	.0157
Average		.0120	.0124	.0144	.0158
High-temperature shipments, 35° to 39° F. (1.7° to 3.9° C.):					
Sept. 13, 1910	2003	.0132	.0154	.0165	.0220
Apr. 26, 1911	2048	.0132	.0126	.0179	.0216
May 3, 1911	2050	.0149	.0150	.0165	.0190
May 23, 1911	2054	.0146	.0124		.0225
June 15, 1911	2056	.0146	.0140	.0148	.0143
July 13, 1911	2060	.0140	.0146	.0154	.0185
Sept. 21, 1911	2065	.0140	.0141	.0178	.0157
Nov. 20, 1911	2071	.0148	.0168	.0151	.0190
May 13, 1911	2084	.0140	.0137	.0140	.0165
Average		.0141	.0143	.0160	.0188

The average temperature at the commission house for the low-temperature shipments was 29.8° F., as compared with 34.2° F. for the high-temperature shipments. The retail store in the interim of low-temperature experiments averaged 35° F., and during high-temperature experiments was 39.3° F. These differences are about half those prevailing during the transit period.

The samples were allowed to remain in the commission house for five days. The first retail sample was withdrawn after four days,

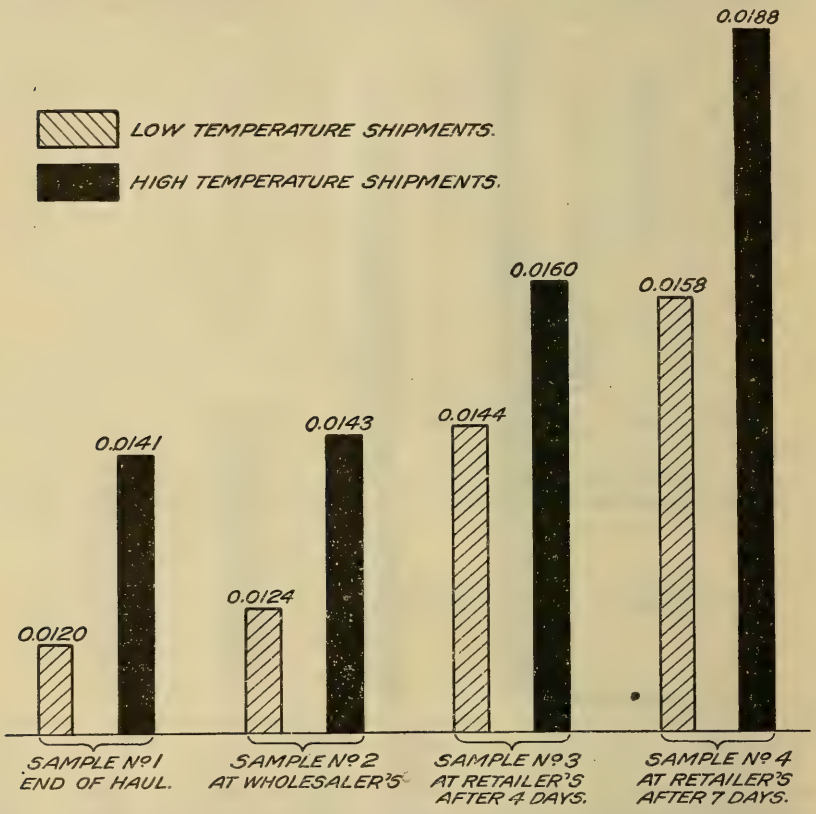

FIG. 3.—Deterioration during marketing period as affected by high and low transportation temperatures, as shown by the percentage of ammoniacal nitrogen.

and the last sample after seven days at the retail store. A graphic representation of the average relative deterioration in low-temperature and high-temperature shipments during the marketing period is given in figure 3. The deterioration in the high-temperature shipments is always at least one stage ahead of the low-temperature shipments. The changes during the commission period are very slight, the temperature in such places being usually low and therefore conducive to preservation. At the end of four days at the retailer's, or nine days after the railroad haul, the ammoniacal nitrogen in the

low-temperature shipments increased to 0.0144 per cent, nearly the same as the high-temperature shipments at the end of the transit period. In other words, if the car temperature is above 35° F. the poultry when it reaches the market has the disadvantage of a deterioration equivalent to five or more days in the market, and to be in the same state of freshness it must be consumed five days earlier than that arriving at car temperatures below 26° F.

These results give some idea of the effect of small differences in temperature on poultry during the market period and indicate that the most favorable temperature for poultry transportation is 30° F. or below. It therefore becomes a fundamental problem in the transportation of dressed poultry and similar products to maintain low temperatures in all parts of the car, which finally resolves itself into a question of car construction.

REFRIGERATOR CARS.

SOURCES OF DATA.

The shipments already described and tabulated in Table 1 were hauled by six different car lines. The cars were of so many different series that they furnished a great variety of sizes, insulations, roofs, doors, ice bunkers, and all of those elements which are factors in the sum total of efficiency.

The car number, the amount of ice and salt used in the initial icing, the temperature of the car before and after loading, the position of the thermographs, the prevailing atmospheric temperature and weather conditions, the re-icing instructions, and the route were all noted at the time of loading. A record of the movements of the cars and the time and amount of ice and salt used in re-icing has been generously furnished by the railroad companies. The railroads have also greatly facilitated this study by freely providing detailed blue prints showing the construction and insulation of the cars in which the experimental shipments were carried.

In some of the experiments the atmospheric temperature was obtained by a thermograph fastened to the outside of the car. In the majority, however, the average between the maximum and minimum atmospheric temperatures was taken each day for the region through which the car was passing, as shown by the daily weather maps and monthly reviews issued by the United States Weather Bureau. The temperature records obtained in this manner coincide almost exactly with those obtained by thermograph on the outside of the car. The inside car temperatures during transit were obtained by thermographs. (See Table 4.)

TABLE 4.—*Comparison of thermograph records of atmospheric temperature and the figures obtained by averaging the United States Weather Bureau reports of the maximum and minimum daily records for the region through which the cars were passing.*

Experiment 5005.				Experiment 5006.				Experiment 5007.			
Date.	Place.	Thermograph.	U. S. Weather Bureau report.	Date.	Place.	Thermograph.	U. S. Weather Bureau report.	Date.	Place.	Thermograph.	U. S. Weather Bureau report.
1912.		°F.	°F.	1912.		°F.	°F.	1912.		°F.	°F.
Mar. 20	Nashville	70	69	Mar. 29	Nashville	57	54	June 1	Lexington	72	73
31	Louisville	48	47	30	Louisville	54	50	2	Cincinnati	67	70
22	Cincinnati	30	33	31	Cincinnati	55	58	3	Marion, Ohio.	71	69
23	Pittsburgh	35	37	Apr. 1	Pittsburgh	56	54	4	Syracuse	69	66
24	Harrisburg	35	35	2	Philadelphia	60	56	5	New York	67	68
25	New York	34	33								
Average		42	42			56	54			69	69

CALCULATION OF THE INDEX OF EFFICIENCY.

To compare the efficiency of the various cars, constructed on widely divergent lines, it becomes necessary to reduce the variable functions, or influencing factors, to a resultant coefficient. Since the purpose of a refrigerator car is to maintain a fixed temperature on the inside, regardless of external temperatures, the ultimate question is one of heat transmission, or the power of all the contributing factors to overcome the heat transmitted from the outside to the inside. Insulation efficiency is usually expressed as the number of B. t. u.[1] transmitted through 1 square foot of the material in a day, for each degree difference in temperature on the colder and warmer sides. Therefore, knowing the amount of ice and salt used, the duration of the haul, and the average temperatures on the inside and outside, the simplest formula for car efficiency would be

$$R = \frac{142\ I + 40.5\ N}{S\ (T - t)\ D} \qquad (1)$$

I = pounds of ice used.
142 = B. t. u. required to melt 1 pound of ice.
N = pounds of salt used.
40.5 = the endothermic heat of solution of 1 pound of salt in a 10 per cent solution at 32° F.
S = the surface exposure of the car.
T = the average atmospheric temperature.
t = the average temperature inside of car.
D = the number of days in the test.

[1] A British thermal unit (B. t. u.) is the quantity of heat required to raise the temperature of a pound of pure water 1 degree Fahrenheit.

R = B. t. u. of heat transmitted through 1 square foot in one day, for each degree difference in temperature; or the amount of refrigeration which must be supplied for each square foot of car surface in a day, for each degree difference in temperature between the atmosphere and the inside.

With thermograph records of the temperature at both bunker and center of car, a fairly accurate average inside temperature may be obtained. The daily maps of the Weather Bureau afford excellent atmospheric data, and with accurate re-icing records the formula gives a very serviceable working comparison of refrigerator cars. The commercial re-icing records are not sufficiently exact for mathematical calculations of efficiency. It is also very difficult to determine from commercial records the weight of the ice which remained in the car bunkers at the end of the haul, and it is consequently impossible to calculate the amount of ice melted. But as it was extremely desirable to make some kind of a comparison of cars which might serve as a working basis or beginning for future experiments, it became necessary to devise a formula which would make R a function of the initial icing, which in these experimental shipments is of acceptable accuracy.

Other factors being constant, a comparative efficiency of cars could be calculated by noting the length of time between the initial icing and the hour at which the temperature on the inside of the car begins to rise; this hour indicates that the ice has spent its maximum strength. No ice is put into the car during this interval. The formula then becomes

$$R^1 = \frac{142\ I + 40.5\ N}{S(T - t)H} \qquad (2)$$

H = the number of hours between icing and the moment at which the temperature in the car begins to rise. R^1, no longer properly designated as B. t. u. because the car still contains unmelted ice, becomes an arbitrary number, but still remains a comparative index of efficiency.

One other correction must be introduced. If the salt, on account of physical conditions in the ice bunker, melts very rapidly and dissolves in the smallest possible amount of water or melted ice, it will lower the temperature of the resulting solution very much more than when it dissolves more slowly and in a larger quantity of water. One per cent of salt with snow or crushed ice lowers the temperature of the mixture on an average of about 1.1° F. between 0° concentration and the point of saturation. If sufficient salt is added to completely saturate the resulting solution, it is possible to reduce the temperature to about −6° F. (−21.1° C.). It is evident that if very low temperatures are produced, the ice will begin to lose its force sooner than if higher temperatures had prevailed, because the total amount of refrigeration available is the same in each case.

In order to give credit to those cars in which low temperatures prevailed at the bunker, H in formula 2 must be a function of the car temperature. The cars were iced 24 hours before loading, and the inside car temperature decreases continually from the time of icing until the door is opened for loading. Therefore 24 of the total number of hours are constant. The variable portion then becomes H^1 where

$$H = 24 + H^1 \qquad (3)$$

H^1 represents the number of hours between loading and the time at which the temperature at the bunker begins to rise.

The bunker should cool the air from the temperature prevailing at the center of the car to that prevailing at the bunker, the temperature maintained at the center depending on the insulation of the car and the circulation of air. The total refrigerating effect might be expressed as degree-hours; that is, if the temperature at the center is C and that at the bunker is B and this difference in temperature is maintained for H^1 hours, the refrigerating effect is $H^1 (C-B)$ degree-hours. If no salt had been used on the ice the bunker air would be 32° F.; but the total refrigerating effect is the same whether the ice melts slowly or rapidly, and therefore the degree-hours at this temperature are $(C-32)\ H^{11}$. Hence

$$H^{11} = \frac{(C-B)\ H^1}{C-32} \qquad (4)$$

As shown by Table 2, 32° F. (0° C.) is too warm for the best results in poultry transportation. The temperature should be 30° F. (−1.1° C.) or lower. In determining the efficiency of the car for maintaining a temperature of 30° F., this number should be substituted in the formula, which then becomes

$$H^{11} = \frac{(C-B)\ H^1}{C-30} \qquad (5)$$

H^{11} represents the number of hours after loading at which the bunker temperature would have started to rise if the bunker had been producing air at 30° F. (−1.1° C.). This reduces all of the car temperatures to a comparative basis; the compensating formula would then be

$$R^1 = \frac{142\ I + 40.5\ N}{S\ (T-t)\ (24+H)^{11}}$$

and, by substitution, the efficiency formula becomes

$$R^1 = \frac{142\ I + 40.5\ N}{S\ (T-t)\left(24 + H^1 \frac{C-B}{C-30}\right)} \qquad (6)$$

The efficiency of the car will vary inversely as R^1, since the greater amount of heat transmitted indicates lower efficiency. If E is the index of efficiency, then $E = \frac{1}{R^1}$

The indices of efficiency obtained by the use of the foregoing formula have served as a basis on which to compare cars of different construction. They are not claimed to be an accurate expression of the resistance of the car to heat transmission nor of its exact capacity for utilizing the refrigerant supplied. To obtain figures mathematically and physically exact would necessitate the recording of the amount of ice and salt used during the period of observation and other data not readily secured from cars in commercial service. It is highly desirable that such accurate figures should be obtained, and it is hoped that the information which this report is able to furnish may lead to the compilation and utilization of such data.

COMPARISON OF CAR EFFICIENCY.

The magnitude of the field of operation covered by this investigation and the complexity of the factors uniting to determine the efficiency of the refrigerated carrier made it highly desirable that some concrete expression be worked out whereby a comparison of the various types of cars studied might be made.

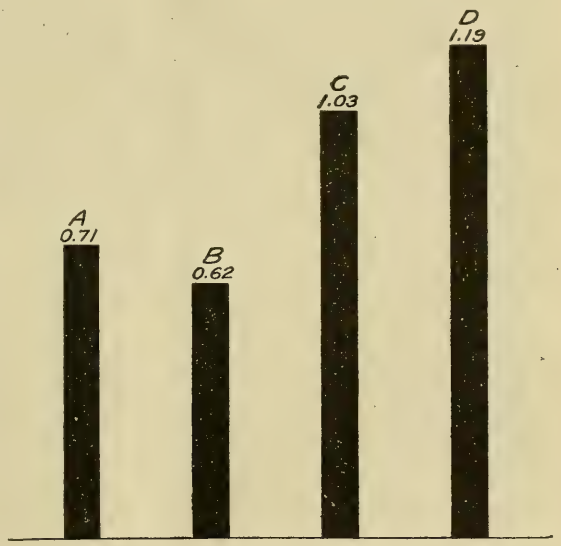

FIG. 4.—Comparative efficiency of cars of types A, B, C, and D.

The application of the formula to the cars used in the experimental shipments results in a wide difference of efficiency indices (see Table 5) for the various types of cars. All of the cars of type A are identical in original construction and are operated by a single company. The cars of type B are alike in ice bunkers and insulation, but, belonging to a different series, they vary in size. The cars of type C are all of the same dimension; likewise those of type D. Each type is operated by one railroad or car company. The four types are unlike each other in many of the essential elements of refrigerator construction, such as the kind and thickness of insulation, its manner of application, ice bunkers, and doors. For the sake of a clearer understanding, the efficiency indices of Table 5 are presented graphically as figure 4, in which the height of the columns increases directly as the efficiency.

TABLE 5.—*Prevailing temperatures and icing records during efficiency tests.*

Experiment No.	Date of loading.	Temperature of atmosphere.				Time after loading before temperature began to rise.	Lowest temperature attained at bunker after loading.	Temperature of car.			Ice added.	Salt added.	Index of efficiency $\left(\frac{1}{E=R^1}\right)$.
		Day before loading.	Day of loading.	Day after loading.	Second day after loading.			Average at center after loading.	Before loading.	After loading.			
Type A:	1910.	°F.	°F.	°F.	°F.	Hrs.	°F.	°F.	°F.	°F.	Pounds.	Per cent.	
1017	Mar. 15	43	44	56	56	20	22	33	28	39	8,400	8	0.72
1021	Apr. 6	45	53	56	56	13	14	34	28	50	7,200	10	.72
1025	Apr. 21	58	69	57	35	14	17	40	32	54	9,600	10	.72
1027	May 4	49	52	52	52	14	14	34	31	47	9,600	10	.70
1029	May 13	55	57	57	57	15	15	33	35	50	11,900	10	.71
Aver.													.71
Type B:	1911.												
2056	June 16	76	81	81	72	10	25	35	37	52	16,000	15	.60
2060	July 14	80	80	81	75	32	36	39	37	52	10,000	10	.60
2062	Sept. 1	74	73	78	75	22	35	39	34	42	12,000	15	.58
2064	Sept. 15	81	84	76	72	12	34	38	41	54	10,000	10	.65
2081	Apr. 30	64	53	66	69	20	35	41	36	48	6,000	10	.63
2083	May 4	72	72	75	67	8	27	36	36	46	10,000	10	.64
2084	May 14	57	56	59	55	9	21	35	30	44	8,000	10	.65
Aver.													.62
Type C:	1912.												
2085	May 25	79	76	67	70	13	24	37	38	50	9,000	10	1.01
2092	Aug. 24	77	77	79	80	18	24	40	38	68	10,000	10	1.04
2093	Aug. 29	82	81	84	84	13	24	37	36	46	10,000	10	1.04
2094	Sept. 20	63	67	70	63	15	19	38	33	48	8,000	10	1.04
2096	Sept. 27	60	61	60	54	18	20	38	31	47	7,000	10	1.05
2099	Oct. 18	63	66	57	55	14	22	36	31	48	7,000	10	1.02
Aver.													1.03
Type D:	1911.												
2059	July 7	81	80	84	80	27	27	41	43	50	10,000	10	1.19
2063	Sept. 8	78	80	77	77	43	37	39	42	47	6,000	10	1.17
	1912.												
2077	Apr. 13	68	69	71	73	16	28	34	41	52	5,800	10	1.22
2078	Apr. 17	63	61	42	46	18	25	34	34	48	5,000	10	1.23
2080	Apr. 16	64	66	64	55	16	27	36	36	48	5,000	10	1.17
2082	May 1	53	64	73	71	27	34	40	31	40	5,000	10	1.17
2089	July 11	76	76	82	82	10	26	33	35	50	7,000	10	1.25
2090	July 26	84	77	74	76	18	29	40	40	60	7,000	10	1.17
2091	Aug. 2	73	78	65	62	40	28	38	40	58	11,000	10	1.12
Aver.													1.19

COMPARISON OF CAR CONSTRUCTION.

With a measure of the gross efficiency of the different types of cars as a working basis, an analysis of the construction of these types will reveal certain features which appear indispensable in effective refrigerator cars.

INSULATION.

There are many kinds of insulating material now in common use, cork, hair felt, wool felt, mineral wool, and various vegetable fibrous materials. The old-time idea of a dead-air space in refrigerator cars is no longer plausible. The car builder has been unable to construct a car with a dead-air space which will remain air and moisture

proof under the continual stress and strain to which refrigerator cars are subjected. Cracks in the boards and punctures in the paper lining soon appear and, with the resulting air circulation, heat is directly transferred from the outside to the inside. A heat insulator is a nonconductor of heat. Heat is a form of energy transferred in waves of extremely small length from one molecule to another. Since the molecules in solid bodies are closer together than those of gases, the solids are the better heat conductors. The more numerous the air spaces in a solid body the more efficient it will be as an insulator.

Cork, the best known insulator, contains innumerable air spaces, and its texture renders it almost impervious to water. It contains but small amounts of gums and resins and practically no nitrogenous material which might serve as a medium for bacterial growth and thus produce decay. Cork, however, has not been used to any extent in car construction, perhaps on account of its expense and the difficulty of its application.

Wool and hair felt are good insulators as long as they are kept dry, but their high percentage of nitrogenous material makes them good bacterial media when moist. Organic oils and acids also aid in their decomposition. These materials, when once moist, seldom dry out, and the result is putrefaction, giving rise to offensive odors, which contaminate the goods in the car. This decomposition not only destroys the insulator itself but rots the board lining with which it comes in contact. Some of the vegetable or cellulose fiber insulators are perhaps slightly more resistant to moisture and bacterial action, but in time they also become moist and their chemical decomposition is hastened by the alkalies present in such material. Of the insulators mentioned, mineral wool is the least subject to decay, but, on the other hand, its physical nonadhesive properties hinder the manufacture of strong material, and its insulating qualities are not as good as those of some of the other nonconductors, although it has the advantage of being fireproof.

Careful consideration of insulation is therefore one of the prime factors in car construction. The material must be of such a nature that it will remain in position, not settling down and leaving hollow spaces in the upper portion of the side walls. It should be impervious to moisture, or be securely protected by moisture-proof material, and as free as possible from decomposable organic matter. The necessary thickness of the insulation depends on the nature of the goods to be transported. Investigations in fruit transportation have shown that temperatures as low as 40° F. are very satisfactory for citrus fruits, but the results with poultry indicate that lower temperatures are essential for a maximum preservation of this class of goods. Aside from the nature of the lading, the question of insulation is one

of economy. Will the saving in ice, resulting from extra insulation, be sufficient to pay for the additional insulation?

Walls.—Figure 5, *a*, *b*, *c*, and *d*, illustrates cross sections through the side walls of the cars of types A, B, C, and D, respectively. Type A is insulated with two thicknesses of half-inch linofelt, one layer on each side of the main frame. There is but one thickness of paper and one sublining in this wall. Type B is insulated in nearly the same manner, except that wool felt is used instead of linofelt. Type C uses one thickness of 1-inch hair felt, compactly arranged between the lining and sublining. There is no attempt in this type to maintain a dead-air space. Type D likewise has a 1-inch layer

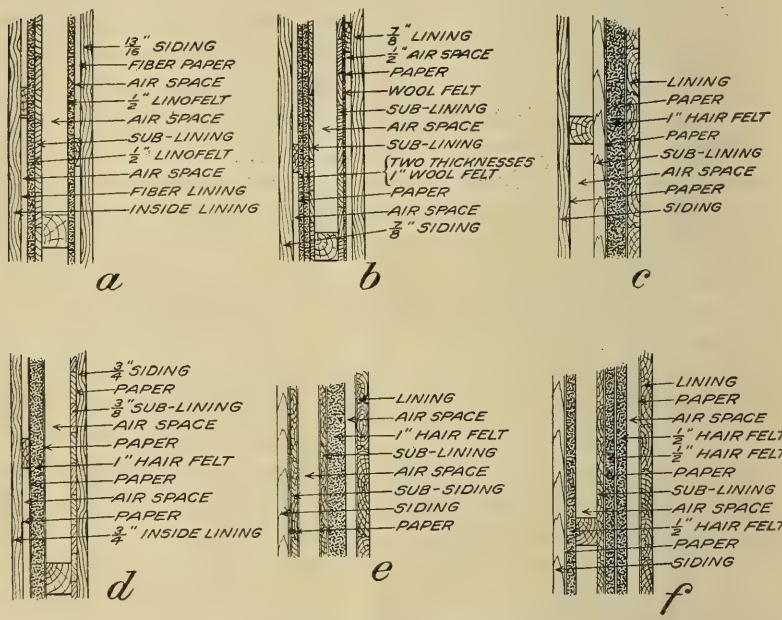

FIG. 5.—Cross sections showing wall construction of different types of refrigerator cars. *a*, Type A; *b*, type B; *c*, type C; *d*, type D; *e*, wall having a 1-inch layer of hair felt; *f*, wall having three half-inch layers of hair felt.

of hair felt, but has not the same solidity; there is an air space on each side of the insulation. Figure 5, *e*, illustrates a side wall with a 1-inch layer of hair felt, supported on one side by a sublining. In this wall there is an additional sublining next to the siding. Figure 5, *f*, shows three half-inch thicknesses of hair felt, two of which are together on the inside of the frame, the other being on the outside of the frame.

Roof.—Figure 6, *a*, illustrates the roof insulation of type A cars. Two thicknesses of one-half inch linofelt are separated by a wide air space. The edges of the insulation are turned up along the sides of the car to give a more compact joint. In appearance this roof

presents a general openness. Type B, with the same thickness of insulation, is more compact, but does not have the upturned edges to protect the corners (fig. 6, *b*). Type C is characterized by a heavy layer of hair felt, 1½ inches thick, packed closely between the ceiling and subceiling with no intervening air space (fig. 6, *c*). In figure 6, *d*, is shown a roof with insulation of the same thickness as the preceding one, but separated into three layers with intervening air spaces. Figure 6, *e*, represents a roof with 2 inches of hair felt insulation, each of the two layers being protected on both sides with

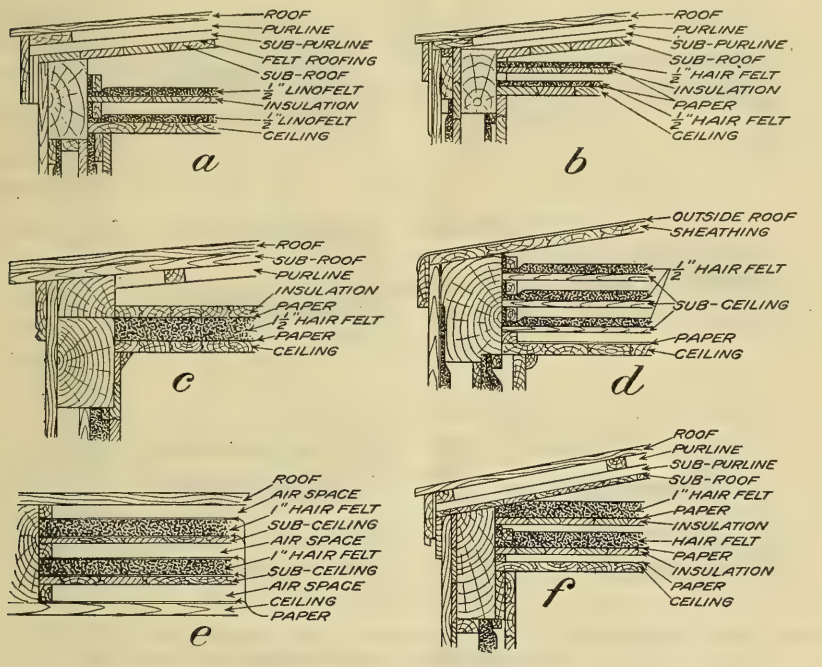

FIG. 6.—Cross sections showing roof insulation of different types of refrigerator cars: *a*, Type A; *b*, type B; *c*, type C; *d*, roof insulation separated into three layers; *e*, roof insulation with 2 inches of hair felt; *f*, type D.

insulation paper. Type D (fig. 6, *f*) also has two thicknesses of 1-inch hair felt, with the additional precaution of upturned edges.

Floor.—The floors of types A and B (fig. 7, *a*, *b*) are equipped with two thicknesses of half-inch insulation separated by air spaces. Types C, D, and F (fig. 7, *c*, *d*, *f*) have one layer 1 inch thick, and type E (fig. 7, *e*) has three layers one-half inch thick, with well-protected joints.

Comparison.—There is but very little difference in the side-wall insulation of the four types of cars whose efficiency indices are given in Table 5. Each type is provided with 1 inch of the non-conducting material. Although the insulation of A and B is divided into two half-inch layers in contrast to the single 1-inch

layer of C and D, the difference in side-wall insulation does not seem sufficient to account for the difference in efficiency. The striking difference in the four types of cars is in the roof insulation. Types A and B, with the low efficiency, have but 1 inch of insulation, and that is divided into two layers with intervening air space. Type C has $1\frac{1}{2}$ inches of solid insulation, and D has two layers, each 1 inch thick. There are undoubtedly several factors which govern the efficiency of a car, but it is worthy of note that the indices of efficiency of Table 5 seem to vary in about the same way as the

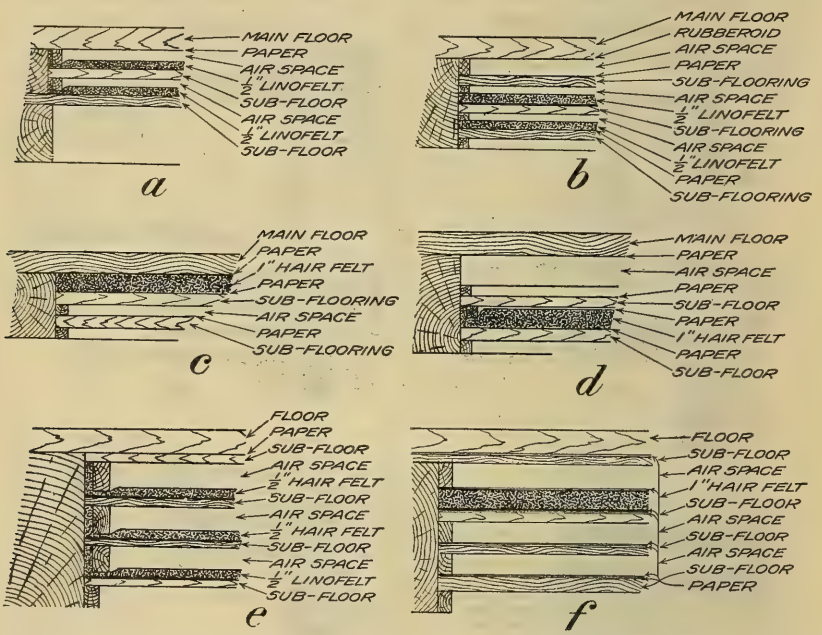

FIG. 7.—Cross sections showing floor insulation of different types of refrigerator cars: *a*, Type A; *b*, type B; *c*, type C; *d*, type D; *e*, floor insulation separated into three layers; *f*, 1-inch layer of hair felt with two uninsulated subfloors.

roof insulation. The floor insulations of the four types are about the same and are very similar in thickness to the walls.

ICE BUNKERS.

Each of the types A, B, C, and D is equipped with a characteristic ice bunker. Type A uses the siphon bunker shown in figure 8. Type B has the galvanized-iron box shown in figure 9, the box being perforated to allow the air to come in contact with the ice. Type C has two large, reenforced wire baskets (fig. 10), which permit free contact with the air. In front of the basket ice holder there is an insulated wall, with an open space at the top of the car for the admission of warm air and a similar space at the bottom for the escape of the cold air. Type D uses the iron tanks shown in figure 11. With such tanks the ice can be crushed very fine, permitting a uniform

and thorough mixing of the salt, which produces very low temperatures. These four, together with the simple box arrangement shown in figure 12, are the types of ice bunkers now in common use. Most of the others are minor modifications of these five.

The various types of cars studied show that there is a wider divergence in the construction of the ice bunkers than in any other single refrigerator-car essential. This is undoubtedly due to a recognition on the part of the car builder of the importance of this fitting in the performance of the car, and the varying forms of the bunker represent the endeavors of the builders to meet modern requirements in the transportation of refrigerated freight. The ice bunker in a refrigerated car holds a place analogous to that of the refrigerating machinery in a stationary plant. It must chill every inch of working space in the compartment depending upon it. It would seem, from the observations made on the types of cars described, that the aim of the builder must be to induce a circulation of air which will convey the lower temperatures at the bunker ends to the center of the car. To do this efficiently the bunker must be assisted by proper insulation on the surfaces of the car.

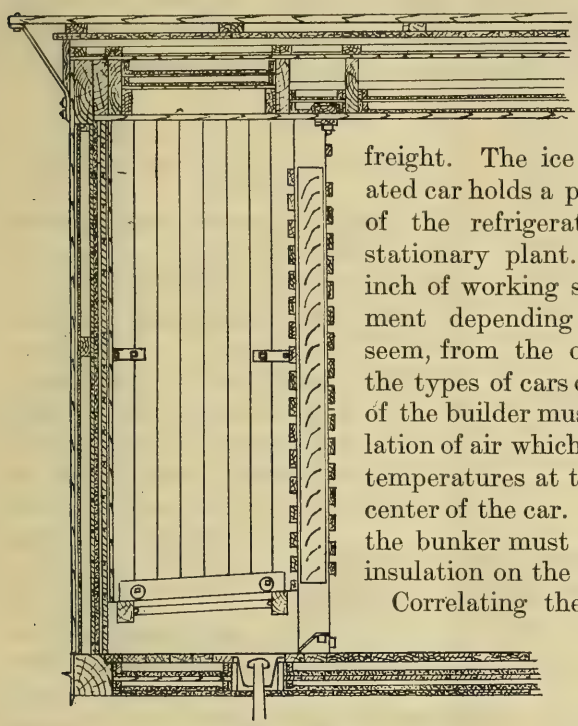

FIG. 8.—Siphon bunker used in type A car.

Correlating the construction of the bunkers with the table of efficiencies of the four types of cars, two essential principles for the production of low temperatures stand out prominently. First, the bunker must permit of the ice being finely crushed and evenly mixed with the salt; and, second, there must be a free admittance of the warm air of the car at the top of the bunker and a free exit of the cold air at the bottom. Such requirements are apparently met most successfully by the tank on the one hand and the wire basket on the other. In this case simplicity of construction has been compatible with efficiency.

Various attempts have been made to use overhead ice bunkers and, in a few instances, brine pipes for circulation have been tried, but in most cases the objectionable features were so numerous that

these systems were soon discarded. Even the best arrangements now in common use leave much to be desired in the way of circulation. Cars of type B (Table 5) show an average difference of 7 degrees between the bunker end and center of the car under ordinary icing. The cars of type D, with heavier insulation, maintain a lower average temperature throughout the car, but, even in this case, the center of the car averages 5° F. warmer than the bunker end. These differences are sometimes disastrous in their effects on poultry shipments.

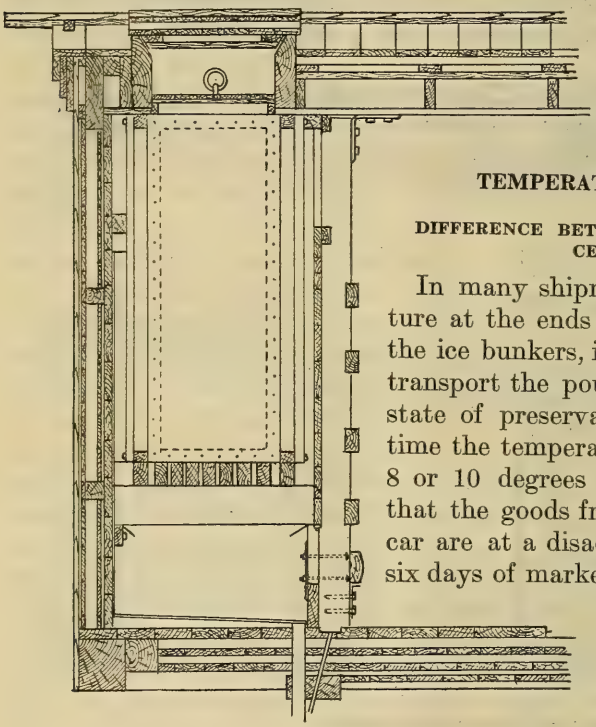

FIG. 9.—Galvanized-iron bunker used in type B car.

TEMPERATURE IN CAR.

DIFFERENCE BETWEEN BUNKER AND CENTER.

In many shipments the temperature at the ends of the car, next to the ice bunkers, is sufficiently low to transport the poultry in an excellent state of preservation. At the same time the temperature at the center, 8 or 10 degrees warmer, is so high that the goods from this part of the car are at a disadvantage of five or six days of market time as compared with the bunker goods.

In figure 13, *a*, is presented the temperature record for the end and center of the car in Experiment 2078, car type D. The atmospheric temperature during the haul averaged 50° F. (10° C.), with a minimum of 42° F. (5.5° C.) and a maximum of 61° F. (16.1° C.). The differences in temperature between the bunker and the center of the car were comparatively small in this shipment, and the analyses of the samples carried at the bunker show good preservation. The findings of the chemical laboratory are in group 1 of Table 2. The efficiency of this car was 1.23.

Figure 13, *b*, shows another shipment, Experiment 2096, car type C, where a wide difference in temperature is manifest between the two positions in the car. The atmospheric temperature averaged 54° F. (12.2° C.), with a minimum of 49° F. (9.4° C.) and a maximum of 61° F. (16.1° C.). The temperature at the bunker was low at the

beginning of the haul, but failed to hold. Samples from this position fall, by chemical analysis, into group 1, Table 2. The efficiency of the car is represented by 1.05.

Figure 13, *c*, *d*, of cars belonging to type C, are the records of Experiments 2085 and 2099, respectively. Experiment 2085, with an outside temperature averaging 72° F. (22.2° C.), gave an efficiency of 1.01; Experiment 2099, with the atmosphere averaging 61° F. (16.1° C.), is represented by 1.02. The analyses of the poultry carried at the bunker ends of these cars are found in group 2, Table 2.

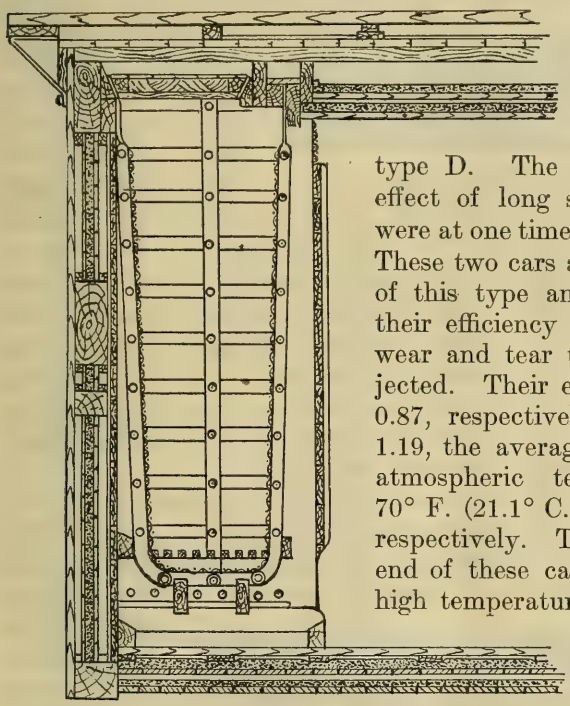

FIG. 10.—Wire basket bunker used in type C car.

Figure 13, *e*, *f*, presents records of samples belonging to Group III, figure 1. The cars were of type D. The records illustrate the effect of long service on cars which were at one time excellent refrigerators. These two cars are of a very old series of this type and seem to have lost their efficiency through the continual wear and tear to which they are subjected. Their efficiency was 0.56 and 0.87, respectively, as compared with 1.19, the average for their type. The atmospheric temperatures averaged 70° F. (21.1° C.) and 77° F. (25° C.), respectively. The goods at the bunker end of these cars show the effects of high temperatures, as may be seen by reference to group 3 of Table 2, or column 3 of figure 2.

Figure 13, *g*, *h*, shows records of shipments which yielded samples of Group IV, figure 1. The cars were of type B, efficiency, 0.60 in each case. The records shown as figure 13, *g*, were made in a comparatively new car, when the outside temperature averaged 74° F. (23.3° C). It was possible to reduce the bunker to a low temperature at the beginning, but as soon as the car started on the trip the temperature began to rise and never receded. The temperature at the center was never low. The records in figure 13, *h*, were both high at all times. This was an older car of type B. The outside temperature averaged 73° F. (22.7° C.), with a maximum variation of 17° F. The differences between bunker end and center are practically lost

in this shipment, the whole car being warmer than is a good refrigerator, even at the bunker. It seems impossible during warm weather to reduce the air at the center of thinly insulated cars to the temperature best suited to the transportation of dressed poultry.

EFFECT OF CAPACITY.

The cars of type D, which are the most efficient of those studied, are likewise the smallest in point of cubic capacity. The total available space in these cars is about 1,640 cubic feet. Type C provides about 1,833 cubic feet of space, but with this increased loading capacity there is a decrease in the power to maintain low temperatures. Type C, however, has one-half inch less insulation on the roof than type D. The cars of type B, which reduce the roof insulation by still another one-half inch, offer about 2,050 cubic feet of space, but at a big sacrifice in efficiency. Type A, with the same insulation as type B, is smaller, 1,909 cubic feet, and is correspondingly higher in efficiency.

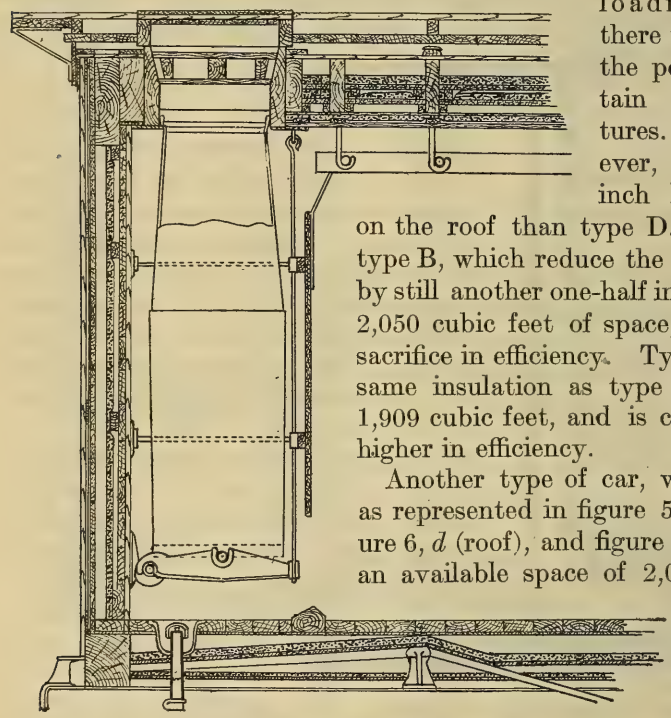

FIG. 11.—Iron tank bunker used in type D car.

Another type of car, with insulation as represented in figure 5, *f* (sides), figure 6, *d* (roof), and figure 7, *e* (floor), has an available space of 2,010 cubic feet. Even with the three layers of one-half inch insulation throughout, there is a wide difference in temperature between the center and ends of the car during warm weather (fig. 14). From this figure it is evident that, in the very large cars, one and one-half inches of insulation is not enough to insure the best temperatures for poultry transportation while comparatively high atmospheric temperatures prevail. Figure 15 gives temperature records in cars insulated, as shown in figure 5, *e* (sides), figure 6, *e* (roof), and figure 7, *f* (floor). These cars are of the large type, but with the 2 inches of insulation on the roof the interior temperatures at the bunker were fairly satisfactory.

The results, as a whole, indicate that large cars require additional insulation to yield the same efficiency as the small cars.

TEMPERATURE OF PACKAGES IN CAR.

During the late winter and spring of 1912 an investigation was made of the variations in the temperature of the poultry in different parts of the barrel and box packages, of the inequalities in temperature in different parts of the car, and of the fluctuations of car temperature as affected by outside atmospheric changes. J. F. Fernald, mechanical assistant, Bureau of Plant Industry, made several trips, accompanying carloads of dressed poultry from Tennessee to the New York and Philadelphia markets. The necessary thermometer readings were made at intervals of three or four hours during the day, at times when the train happened to be at rest.

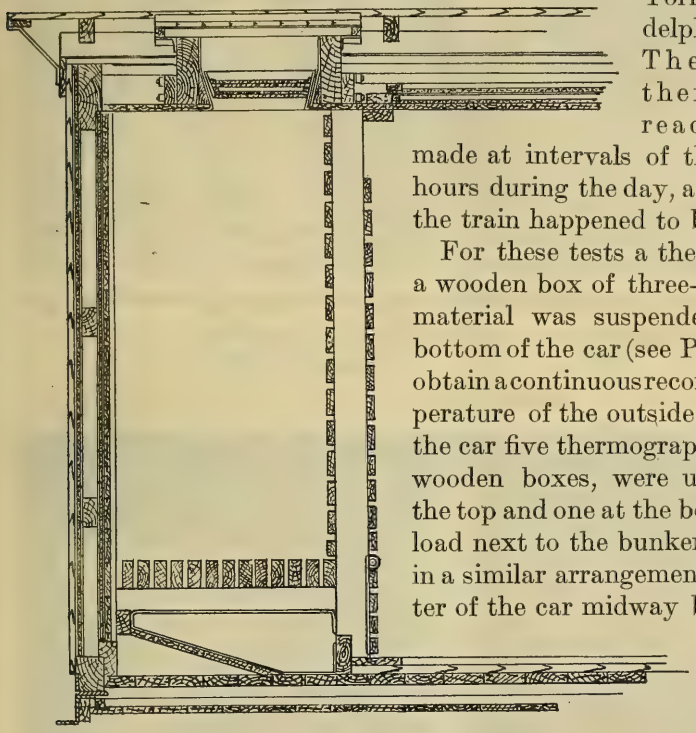

FIG. 12.—Simple box bunker.

For these tests a thermograph in a wooden box of three-fourths inch material was suspended from the bottom of the car (see Pl. I, fig. 1), to obtain a continuous record of the temperature of the outside air. Inside the car five thermographs, in similar wooden boxes, were used—one at the top and one at the bottom of the load next to the bunker, two others in a similar arrangement at the center of the car midway between the doors, and the fifth next to the side wall of the car.

These thermograph records were supplemented with the readings of eight electric thermometers, located at similar positions in the car (see Pl. I, fig. 2). The conduit wires from the thermometers converged in a small holder or box which was suspended just beneath the lid of the ice hatch at a point which would be easily accessible from the top of the car. From this position the thermometers were read by means of an electric apparatus carried by the messenger in charge. This operation was performed without opening the car doors, and was thus protected against the admission of warm air and artificial air currents. These electric thermometers are about 10 inches long and

one-half inch in diameter, and when used to determine the temperature of the poultry they were inserted entirely into the box or barrel, and not disturbed during the transit period.

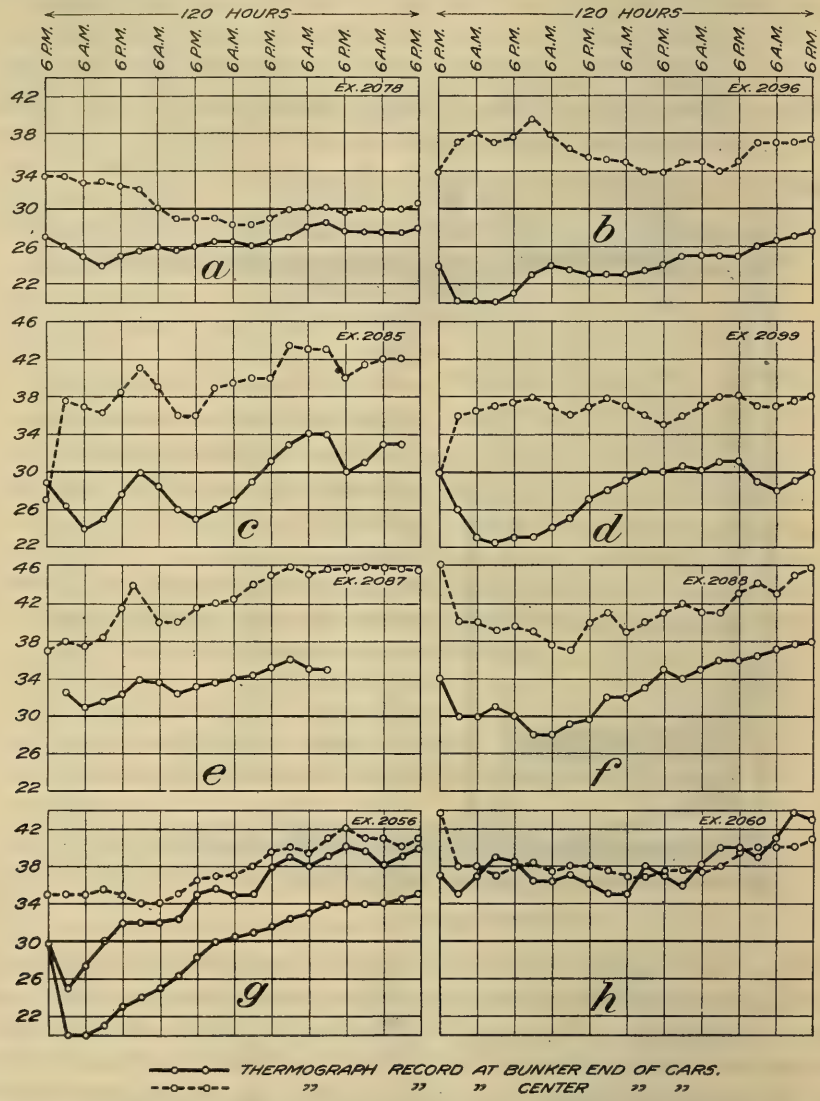

FIG. 13.—Typical car records for routine shipments. Data for these shipments will be found in Table 2, as follows: *a*, *b*, in group 1; *c*, *d*, in group 2; *e*, *f*, in group 3; *g*, *h*, in group 4.

COLD WEATHER SHIPMENTS.

The chart shown as figure 16 presents the record of a car shipped in February, 1912, from Tennessee to New York City. The weather was cold during the entire trip. The thermographs, in wooden boxes,

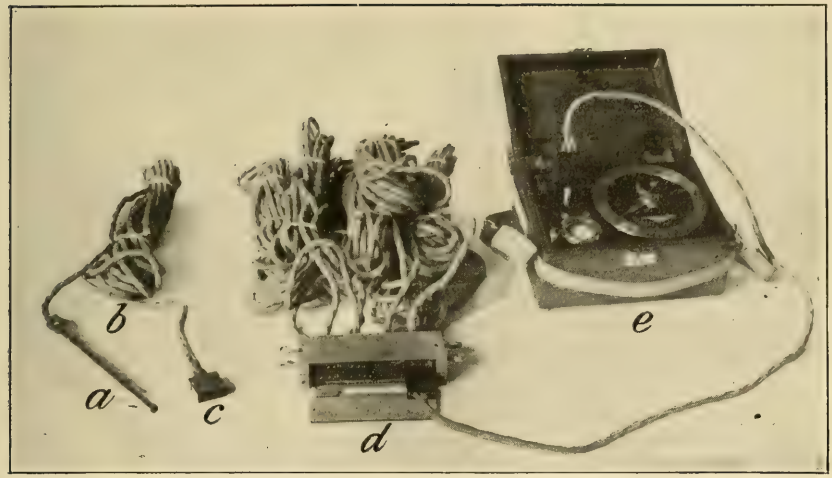

FIG. 1.—RESISTANCE THERMOMETER.

a, Thermometer; *b*, leader; *c*, plug; *d*, plug box; *e*, indicator.

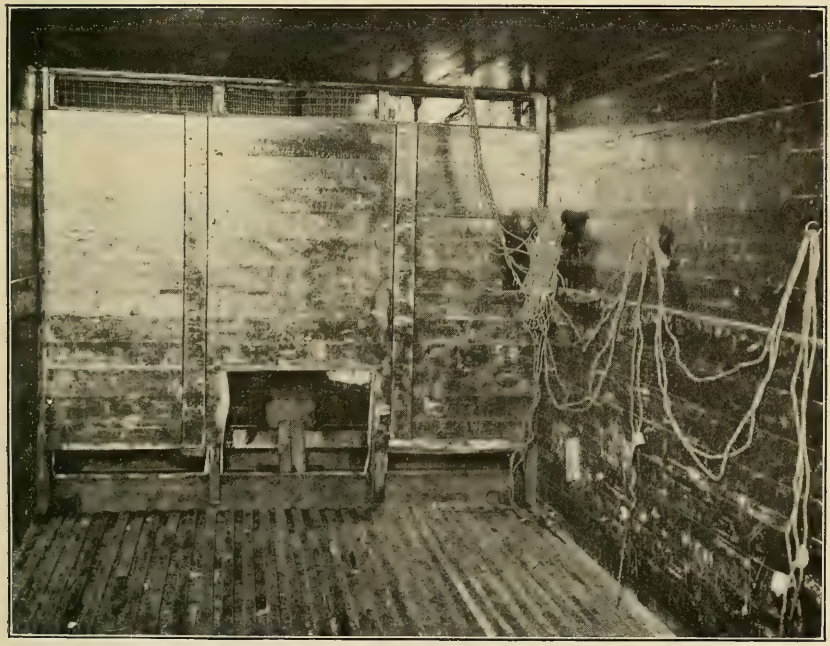

FIG. 2.—ELECTRIC THERMOMETERS IN CAR.

were in immediate contact with the poultry packages containing the electric thermometers. The records are given in pairs, thermograph and thermometer, according to their position in the car. The temperature of the air in the car was not appreciably affected by the small changes which occurred in the atmospheric temperature. The temperature inside the poultry boxes was almost constant, even in those packages next to the bunker where the temperature of the air was 7 or 8 degrees lower for a day or two. The car in which this shipment was made was of type C (Table 5). Figure 17 presents the records of a shipment made in a type B car in very cold weather. The fluctuation in car temperature was marked and was very similar in all parts of the car.

WARM WEATHER SHIPMENTS.

The records of a shipment made in April are shown as figure 18. The weather was warmer than that which prevailed during the two shipments previously described. This experiment again shows that the temperature of the poultry does not fluctuate with the wide changes of the air of the car. Its fluctuations are much slower and smaller. The lower chart indicates the usual prevailing difference in temperature between the bunker end and center of the car.

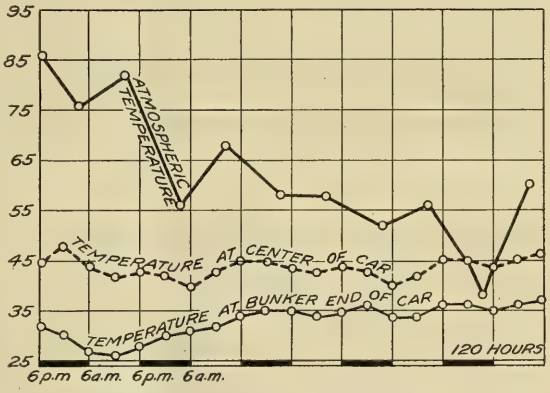

FIG. 14.—Temperatures in large car with three layers of half-inch insulation on roof, walls, and floor.

The charts shown as figure 19 are a detailed representation of the temperature records of a shipment made in April, 1912. This car was accompanied throughout the trip by two messengers. The poultry was packed in small barrels, or kegs, which were loaded in a single course, one barrel high. Sections I, II, and III of this chart are thermograph records, and IV, V, and VI are electric thermometer records.

The car, which was of type C, was insulated with hair felt, which in the floor was water soaked and very much decomposed. This faulty floor reduced the efficiency of the car to 0.71 as compared with 1.03, the average for this type. It resulted, in some instances, in higher temperatures at the floor than at the top of the barrel.

The temperature (F) of the poultry in the middle of the barrel next to the bunker changed very little, the change being much slower than in the air outside of the barrel (K and L). Thermometers, G and H,

on the inside of the barrel next to the side wall of the car, half way between the bunker and door, showed a gradual rise of temperature, G reaching 36.5° F. (2.2° C.). It is interesting to note that on account of the wet floor the poultry in the bottom half of the barrel was sometimes 2 or 3 degrees warmer than that in the top half. The poultry in the middle portion of the car, away from the side walls, was likewise gradually increasing in temperature (J), but lagged far behind the temperature of the air in the car. The air in the car became warmer

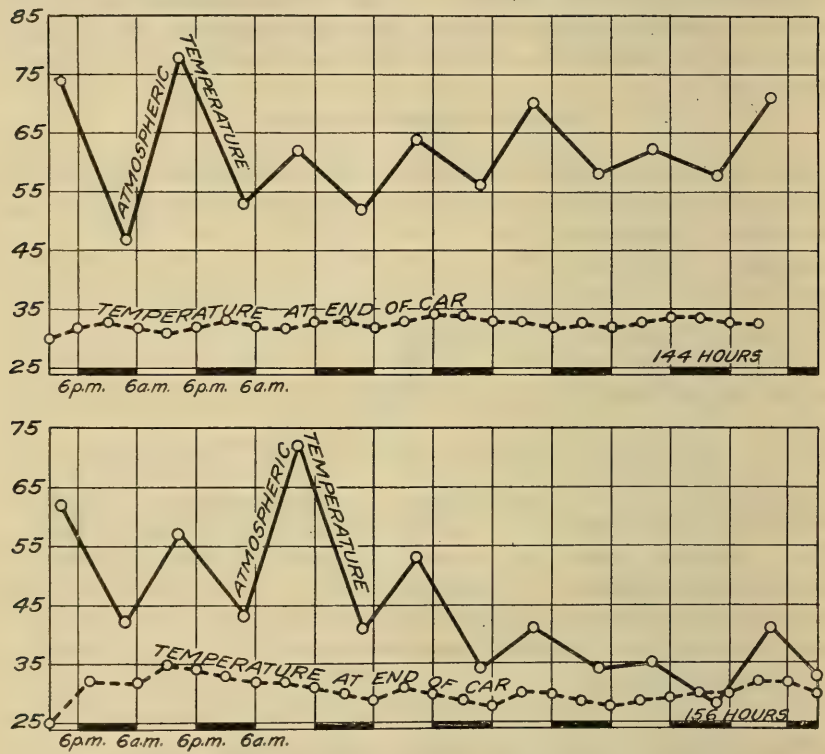

FIG. 15.—Temperatures in large cars with 2 inches of insulation on roof.

during the day and again colder at night (III, VI). Even the temperature inside the poultry barrel along the side of the car was noticeably influenced (V, G) by the warm atmosphere during the day.

CONCLUSIONS.

The chemical data obtained by analyzing well-handled, dry-packed, dressed poultry after transportation in refrigerator cars indicate that the condition of this commodity is greatly influenced by the temperatures prevailing in the car throughout the transit period. The railroads have recognized that "dairy freight," which includes dressed poultry, eggs, and butter, requires refrigerator service for the greater

part of the year. Because of the fact that this class of goods is admittedly extremely perishable, the railroads have endeavored to perfect its transportation, but, lacking definite information concerning either the detriment or the benefit of present equipment and practices, the advances have of necessity been slow.

Temperatures for dressed poultry.—The experiments indicate that less than 31° F. is the most satisfactory temperature of dressed poultry for long hauls. It will be seen, by referring to figure 2, that

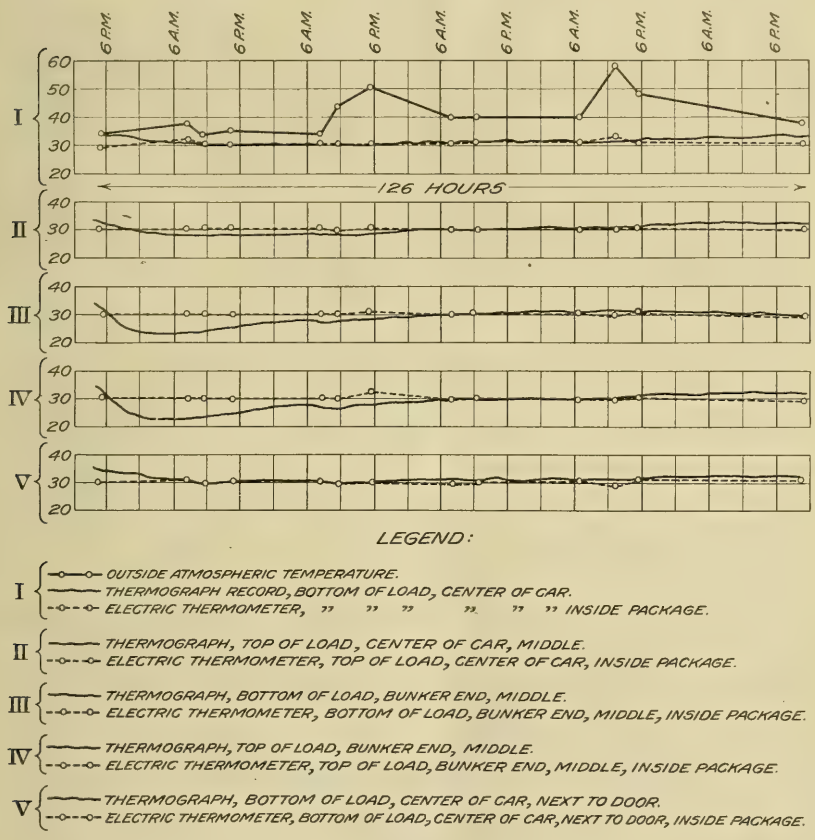

FIG. 16.—Thermograph and electric thermometer records in cold-weather shipment.

a 10-degree rise in the temperature of the car during the haul makes a difference in keeping time of at least five days on the New York market when the market environment is favorable. Such an observation is worthy of the serious attention of shippers, receivers, and carriers, since all feel the depression that ultimately results from putting poor goods on the market. More far-reaching, however, is the further observation, pictured in figure 3, that even such excellently handled poultry as comprised these experimental shipments, if exposed to

unfavorable temperatures during transportation, receive an impetus toward decay that can not be overcome by subsequent irreproachable treatment on the market. It is a comparatively simple matter to prevent decay; it is, at the present time, impossible to stop it by the use of low temperatures once a foothold has been gained. Imperfect

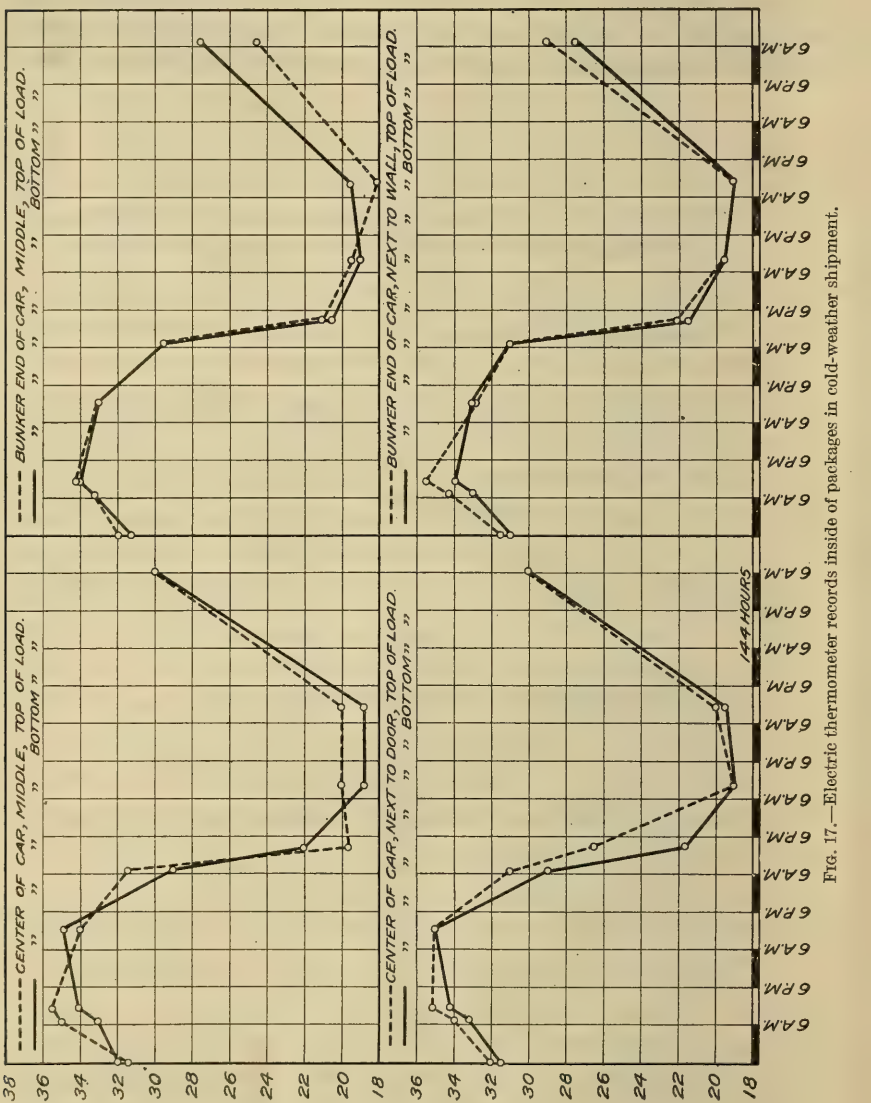

FIG. 17.—Electric thermometer records inside of packages in cold-weather shipment.

work by the carrier nullifies to a certain extent the work of the shipper and the wholesaler or retailer handling the goods on the market. The temperatures indicated by this investigation to be most desirable for the transportation of dressed poultry are considerably lower than those generally accepte as satisfactory. They are, however, quite in

line with scientific findings and practical experience in the preservation of dressed poultry by refrigeration in the packing plants and warehouses. That definite standards have not heretofore been applied to the performance of a refrigerator car is due to the difficulty of accurately determining what takes place between the closing of the car doors and its arrival at its destination. Without such information car builders were working more or less in the dark.

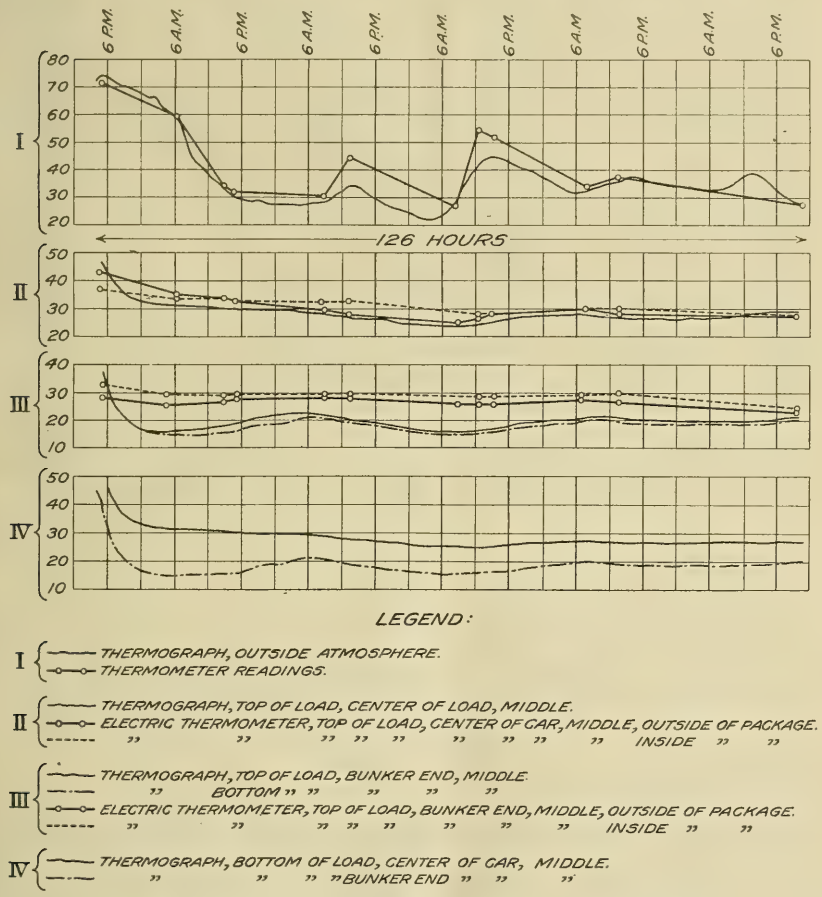

FIG. 18.—Thermograph and electric thermometer records (April shipment).

Efficiency of cars.—If the information furnished by 120 car-lot shipments of dressed poultry in 120 individual cars of six different lines can be accepted as conclusive, we must infer that most of the refrigerated carriers of the United States are not able to maintain sufficiently low temperatures during warm weather to transport a low-temperature commodity, such as dressed poultry, under the best of conditions. It is encouraging to observe that certain refrigerator cars are much more efficient than others, and that their increased efficiency apparently depends upon their construction.

The insulation of the car in relation to temperature is its most vulnerable and its most important part, the construction of the ice bunker coming next in importance. In the past the insulation has not been sufficiently heavy to maintain the low temperatures produced by the refrigerant, and the source of refrigeration, the bunker, has not been able to distribute its product evenly throughout the car.

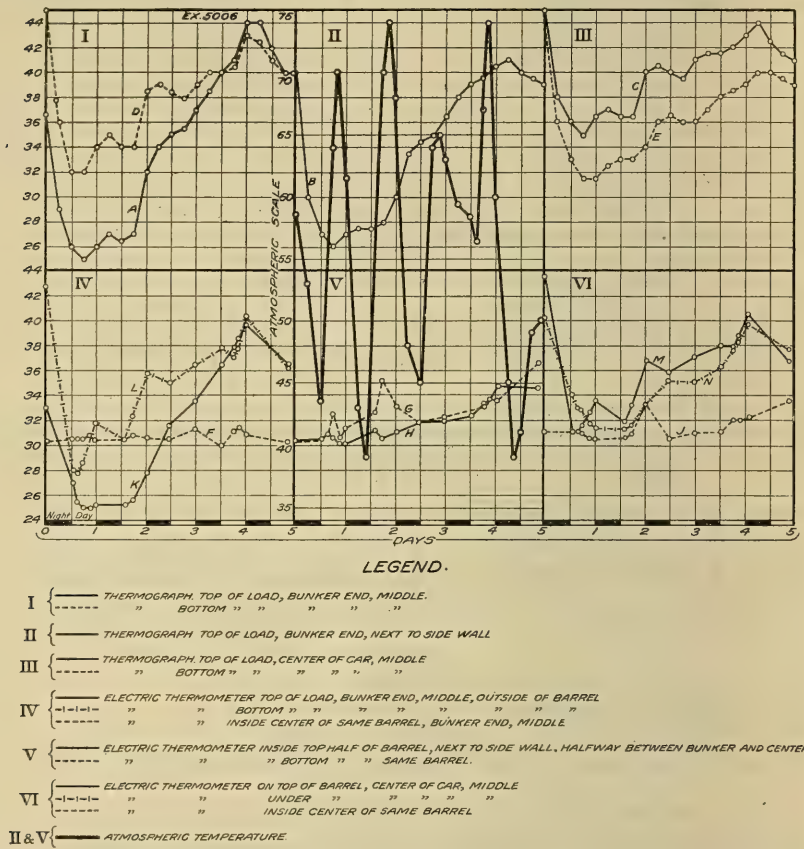

FIG. 19.—Thermograph and electric thermometer records (warm weather), floor insulation of car wet.

The insulation in the side walls and floors of the cars used by six different lines shows no radical differences in quantity or quality, though the general construction in certain cases is preferable. The roofs are varied in the essentials of construction. Theoretically it is the roof of the car which is most severely taxed to prevent the transmission of heat. A critical study of the types of roof construction as given in the foregoing pages indicates that the most efficient cars studied were those with the roofs which were the best insulated and built. It is probable that in the future more attention will be paid to both roof and floor insulation and that the floor will be built with the insulation more effectively protected against moisture.

The ice bunker.—Looking into the future through the glasses of the present, one sees trains of classified freight supplied with refrigeration from a portable, mechanical source. Until that dream is a reality it behooves us to raise the work of the ice bunker to its maximum capacity. The types of bunker most commonly used are sketched and described in this report. The most efficient would seem to be an emphatic indorsement of simplicity of construction based upon a sound scientific foundation. We know that abundant air access to ice and salt results in increased efficiency; hence the principle of the wire basket is sound. We know also that the brine resulting from the solution of the salt in the melted ice contains available cold; hence the holding back of the brine in the tank bunker increases the ability of the bunker to chill the car.

Equality of temperatures in iced cars.—A serious shortcoming of the present types of refrigerator cars is their almost universal inability to equalize the temperature at the center and at the bunker, keeping both sufficiently low. Undoubtedly good bunkers and additional insulation, assisted by a stowing of the load in such a way that runways for cold air are left between packages, will materially help to improve results, but whether these remedies will suffice is still an open question.

Fortunately for the preservation of the poultry shipped, the well-cooled package does not show fluctuations of temperature corresponding to those in the air of the car. A long-continued increase of temperature, or a direct contact between the package and the source of the heat, as, for example, the wall of the car, affects the temperature of the goods in the course of time. Sometimes the packages show slight evidences of the daily rise and nightly fall of temperature, but more often it is the gradual but constant or maintained rise in the temperature of the car that is responsible for the objectionable results seen at the expiration of the haul.

Future work.—The investigation which is here chronicled is only a small beginning in the solution of the problems confronting the shipper, the carrier, and the receiver in the handling of refrigerated perishable products. It is eminently necessary that such questions as the most efficient and economic size of the refrigerated car, the exact amount of insulation required to insure the maintenance of low temperatures, or, conversely, to protect the contents of the car against frost, the equalization of temperatures in all parts of the car, and many others, be pressed for more exact and far-reaching answers. It is hoped that the present report will stimulate further research in these and in other directions.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 18

Contribution from the Bureau of Soils, Milton Whitney, Chief,
October 1, 1913.

A REPORT ON THE PHOSPHATE FIELDS OF SOUTH CAROLINA.

By Wm. H. Waggaman,
Scientist in Investigation of Fertilizer Resources.

INTRODUCTION.

The first important discoveries of phosphorites or amorphous phosphates made in this country were those of South Carolina. For many years these fields furnished most of our supply and much of Europe's. But during the last 20 years the output has been gradually diminishing, owing in part to the exhaustion of the more readily accessible rock, but chiefly to the marketing of higher-grade phosphate from other sources.

Although many interesting and valuable articles and papers on these deposits have been published from the time of their first exploration in 1868 down to the year 1904, conditions in these fields have changed so materially during the last decade that it is thought advisable to issue the present bulletin. This reviews briefly the history of South Carolina phosphates, describes the present methods of mining and handling the rock, shows what disposal is being made of the product, and discusses the future of the industry.

HISTORY.

The existence of the phosphate stratum was known for many years before its true nature and value were recognized. As far back as 1839 [1] the upper portion of the heavy marl (including the phosphate stratum) was known as the "Fish Bed" of the Charleston Basin on account of the numerous teeth and bones of marine animals contained therein. In 1842 Edmund Ruffin [2] made an agricultural survey of South Carolina, but his report, which was issued the following year, dealt chiefly with the occurrence and extent of the marls of the State. Holmes [3] states that he and some of his associates submitted samples of the nodular phosphate to Ruffin for examination, but apparently

[1] Holmes, F. S. The Phosphate Rocks of South Carolina, p. 65 (1870).
[2] Chazal. A Sketch of the South Carolina Phosphate Industry, p. 34 (1904).
[3] The Phosphate Rocks of South Carolina, p. 57 (1870).

no determination other than that of their lime content was made. Holmes,[1] in 1844, described "a remarkable bed of nodules or conglomerates 12 inches thick bedded in clay which overlaid the heavy beds of marl."

Tuomey,[2] who succeeded Ruffin, issued a report in 1848 in which he described the same stratum and called the phosphate nodules "marl stones." He was convinced that they were derived from the underlying marl, for he says, "There is little more left than the silica and alumina of the marl." In the appendix of this same report [3] are a number of analyses made by Prof. Charles U. Shepard showing the phosphate content of the marl, but none showing the amount of phosphoric acid in the nodules. Holmes,[4] in a later publication, also regards the phosphate nodules as silicified fragments of the underlying marl.

Chazal[5] states that Prof. Charles U. Shepard was the first to point out the true value of the phosphate nodules. He quotes from a lecture delivered by Shepard before the medical society in 1859, which indicates that the latter was then acquainted with the nature of the phosphate stratum. Chazal also quotes from letters which show that Shepard had advised the use of the Ashley phosphates in lieu of bones as far back as 1860. The outbreak of the Civil War, however, put a stop to fertilizer operations, and it was not until 1867 that Dr. St. Julien Ravanel, Dr. F. S. Holmes, and Dr. N. A. Pratt revived interest in these deposits and obtained capital sufficient for their exploitation. To Dr. Pratt belongs the credit of the first recorded analysis of high-grade South Carolina phosphate.

From 1868, when 12,262 tons of rock were produced from the South Carolina fields, to the year 1893, which showed a production of 618,569 tons, the industry steadily grew, but since the latter date the production has diminished, till in 1911 the total amount mined was only 169,156 tons.

GEOGRAPHY AND TOPOGRAPHY.

The phosphate area of South Carolina lies along the coast in a belt, which is in places fully 20 miles wide, extending from the Wando River in Charleston County to the Broad River in Beaufort County. (See fig. 1.) The coast region as a whole is very little above tide level and is intersected with numerous creeks, rivers, and arms of the sea. Most of these streams are navigable and afford the phosphate operators a ready means of transportation for their product. Many of

[1] South Carolina Agriculturist (1844).
[2] Geology of South Carolina, p. 165 (1848).
[3] Geology of South Carolina. Appendix (1848).
[4] Post Pliocene Fossils of South Carolina. Introduction, p. II (1860).
[5] A Sketch of the South Carolina Phosphate Industry (1904).

the phosphate properties are reached by the Atlantic Coast Line, the Southern, and the Charleston & Western Carolina Railroads, or spurs from these roads.

CLASSES OF PHOSPHATE.

The South Carolina phosphate deposits are usually classified under two heads, namely, the "River Rock" and the "Land Rock."

The River Rock was at first the most easily exploited, since it was cleaner and after being dredged from the river bed required but little

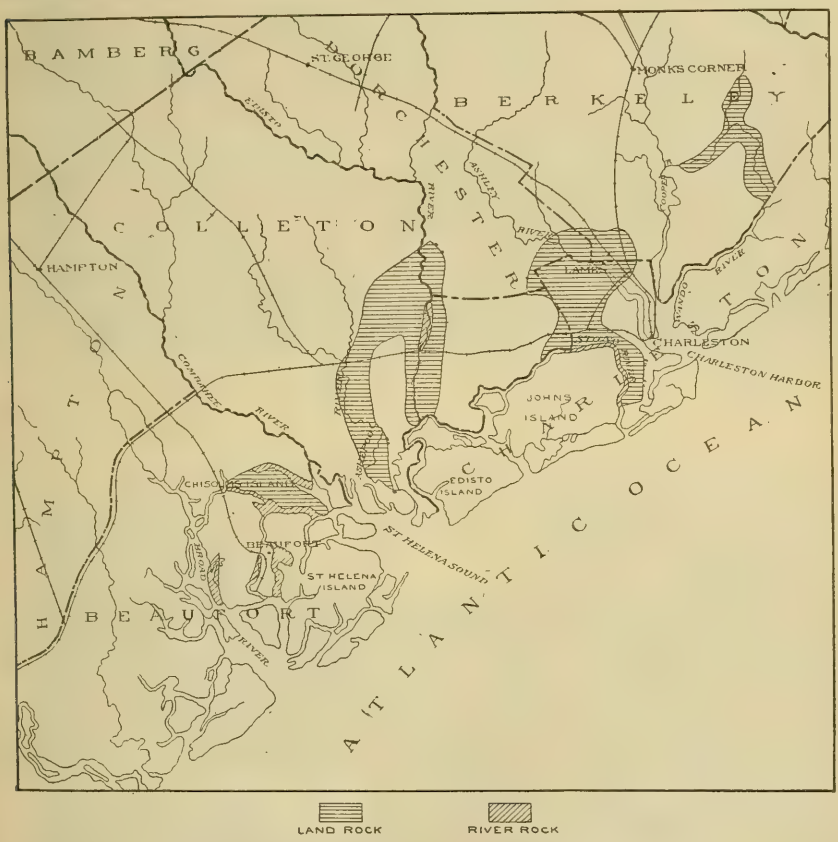

FIG. 1.—Approximate distribution of the South Carolina phosphates.

subsequent treatment to make it a marketable product. It was some time before a satisfactory method of mining and cleaning Land Rock was devised. The two types of phosphate, however, are practically identical, the River Rock being merely the Land Rock washed down and concentrated in the river beds.

The mining of River phosphate has now ceased and the rock shipped from South Carolina is all from the land and marsh deposits. This report, therefore, deals chiefly with the land deposits.

GEOLOGICAL OCCURRENCE AND ORIGIN.

The phosphate-bearing stratum belongs to the Tertiary period, but geologists differ considerably regarding the exact age of the phosphate.

Toumey[1] is of the opinion that the phosphate nodules are derived from the fragments of the Eocene marl on which the beds rest. This author, however, was unacquainted with the true nature of the phosphate. Holmes,[2] Shepard,[3] and Chazal[4] also think the nodules are waterworn fragments of the Eocene marl enriched by the leaching out of the carbonate of lime and absorption of phosphoric acid from solution. These authors assign the phosphate stratum to the post-Pliocene formation. Chazal points out that it is hardly likely that the nodules have derived their phosphoric acid from the animal remains with which they are mingled, since these remains themselves have been enriched by phosphatization after deposition. Levat[5] and Brown[6]—the latter quoting extensively from the former—agree with the above authors concerning the origin of the phosphate, but say it occurs at the Miocene horizon. Pratt[7] thinks it belongs to an even more recent formation and that it is derived from the feces and remains of both terrestrial and marine animals intermingled with disintegrated coral and deposited in the form of a calcareous and phosphatic mud. He considers the present beds the result of fresh-water rivers cutting through the phosphate strata and separating the more from the less valuable material. This author thinks the formation of these beds is still going on. Dall,[8] from an examination of the fossils, states without hesitation that the phosphate is derived from rocks of Miocene age and thinks it doubtful if the underlying marl belongs to the Eocene.

The phosphate occurs in the form of nodules and bowlders embedded in a matrix of sand, clay, and calcareous mud. The beds vary from a few inches to 3 feet in thickness, with an average thickness of approximately 1 foot.

The nodules average from 30 to 50 per cent of the phosphate stratum, and the beds will yield from 300 to 1,500 tons of phosphate per acre, with an average of about 850 tons. The beds, as a rule, do not follow the coutour of the land surface, but lie nearly horizontal. The overburden, therefore, varies considerably from place to place.

Although only the upper stratum is mined, phosphate nodules are found at more than one horizon. The following table of Prof.

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[1] Geology of South Carolina, pp. 164, 165 (1848).
[2] Phosphate Rocks of South Carolina, pp. 27–31 (1870).
[3] South Carolina Phosphates, pp. 22–24 (1880).
[4] A Sketch of the South Carolina Phosphate Industry (1904).
[5] Industrie des Phosphates et Superphosphates, pp. 83–84.
[6] Eng. Assoc. of the South Trans. 15, pp. 58–60 (1904).
[7] Native Bone Phosphates of South Carolina, pp. 24–28 (1868).
[8] Amer. Jour. Sci., ser. 3, p. 296 (1894).

FIG. 1.—HAND MINING. REMOVING OVERBURDEN FROM SOUTH CAROLINA PHOSPHATE.

FIG. 2.—LOADING PHOSPHATE ON FLAT CARS BY HAND.

Shepard, published by Chazal,[1] shows the various strata and their content of phosphoric acid.

TABLE 1.—*Thickness and character of strata in phosphate regions of South Carolina as determined from a well.*

Character of stratum.	Depth of strata.	Content of phosphoric acid.	Equivalent in bone phosphate of lime.
	Feet.	*Per cent.*	*Per cent.*
Clay	17–20	0.42	0.92
Phosphatic nodules	26–30	26.79	58.48
Marl	26–30	3.07	6.70
Do	34	3.01	6.67
Argillaceous marl	46	2.03	4.43
Phosphatic nodules	70	22.72	49.59
Argillaceous marl	85	1.26	2.74
Do	90	1.51	3.30
Phosphatic nodules	104	13.38	29.20
Do	110–112	23.60	51.52
Argillaceous marl[1]	110–112	10.65	23.24
Phosphatic nodules	125–128	15.81	34.91
Hard marl	125–128	1.23	2.68
Argillaceous marl	145	Traces.	
Do	170	Traces.	
Do	228	Traces.	
Do	255	Traces.	
Phosphatic nodules	280	22.47	49.05
Argillaceous marl	286	.60	1.31
Marl and phosphatic grains	287–290	5.96	13.01
Argillaceous marl	300–305	3.37	7.37
Sandy marl	305–306	.90	1.96
Do	307	.80	1.75
Hard marl	309–311	.63	1.37
Phosphatic pebbles	312–313	27.72	60.52
Hard pebbly marl	312–313	2.47	5.39
Sandy limestone	315–316	1.02	2.22
Firm limestone	321–322	.95	2.07
Sandy limestone	323	1.05	2.29

[1] Including phosphatic nodules.

PHYSICAL AND CHEMICAL PROPERTIES.

The South Carolina phosphates occur in nodules varying from the size of sand grains to bowlders weighing several tons. The rock varies in hardness and texture from soft porous material to hard, lustrous, flintlike pieces. The nodules are sometimes smooth rounded or kidney shaped, closely resembling "coprolites," but more often they are irregular in shape, pitted, or completely perforated, the holes usually being filled with sand and clay, which has to be removed by washing. In color the rock varies from grayish white to almost jet black, and between these two extremes there are a variety of shades of red, yellow, and brown.

The River Rock and that found in the marshes is usually darker in color than that found farther inland, owing probably to a larger percentage of organic matter. The rock varies in specific gravity from 2 to 2.5; and from a large number of determinations made by Shepard the average is 2.4. The nodules are usually denser and harder on their surface than in the interior, but this is not always so.

[1] Sketch of the South Carolina Phosphate Industry, p. 26 (1904).

After calcining, the rock becomes more brittle and can be readily and cheaply ground.

Although the South Carolina phosphate is considerably lower in grade than that from many other sources, it makes an acid phosphate of excellent quality and good mechanical condition for mixing purposes. Some farmers prefer this material to the higher grade product made from Florida or Tennessee phosphate.

The rock now marketed contains on the average about 61 per cent of bone phosphate of lime, though individual nodules and fragments are sometimes found which contain as much as 75 per cent. The following table, compiled by Chazal from analyses made by Shepard, gives the composition of South Carolina phosphate from different localities. The samples from which these analyses were made were collected during the early development of the South Carolina phosphate industry and are of somewhat lower grade than the rock which is now obtained from some of the same localities.

TABLE II.—*Phosphate content of South Carolina phosphate rock from various sources.*

Location.	Description.	Moisture.	P_2O_5, undried basis.	$Ca_3(PO_4)_2$, undried basis.	$Ca_3(PO_4)_2$, dried basis.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Stone River	Light colored	3.68	25.61	55.91	58.04
Do	Dark colored		20.68	58.24	
Do	Large bowlder	1.50	25.70	56.21	57.07
Ashley River, land deposit	Hot air-dried cargo sample	.00	27.01	58.95	58.95
Cooper River, land deposit		10.07	27.11	59.18	
Chisolms Island	Hot air-dried cargo sample	.84	27.26	59.51	60.00
Bull River	do	.79	25.14	54.88	55.32
Coosaw River	do	.57	27.26	59.51	59.85
Do	do	.66	26.78	58.46	58.85

METHODS OF MINING.

For many years the mining of South Carolina phosphate was carried on by hand labor. For a short time even the washing of the phosphate was done by hand. The product, therefore, was at first regarded rather unfavorably, as it was not clean and produced an acid phosphate of poor quality. The early methods of mining and handling the rock have been largely supplanted by modern and more efficient methods, which turn out a clean, dry product well fitted for the manufacture of acid phosphate. Hand mining is still economically practiced where the overburden is sufficiently light and of such a character as to render the steam shovel unnecessary, but washing by hand has been entirely supplanted by the modern washer plant capable of turning out from 150 to 600 tons of clean rock every day. Hand mining (see Pl. I, figs. 1 and 2) is carried out as follows:

After thorough prospecting to determine the extent and value of the phosphate property, a ditch is dug through or alongside the tract to be mined and below the level of the phosphate stratum. Laterals

drain into this ditch from the phosphate trenches, which are thus kept comparatively dry. A main line of railroad is established, and spurs from this are run out to the phosphate trenches in such a way that the material can be loaded easily into flat cars and hauled cheaply to the washer plant.

Hand mining is usually performed on contract, a certain price being paid for the rock delivered at the washer. The contractor in turn pays the laborers by the task, assigning each man a section of the phosphate property, from which he removes the overburden and digs out the phosphate and loads it on the cars. Where the overburden is 8 feet or more in thickness steam shovels are employed to remove it. This machine digs a canal about 20 feet wide, depositing the overburden on one bank, while a hoist equipped with a single grab bucket, or a series of buckets to be loaded by hand, runs on a track on the opposite bank of the canal. As fast as the steam shovel removes the overburden from the deposit the hoist is used to place the phosphate thus exposed on the cars. When the limit of the deposit is reached the steam shovel returns, dredging out a canal adjacent to that already dug and depositing the overburden in the old ditch. Many deposits which could not be economically worked by hand are now rendered valuable by the advent of machine mining. (Pl. II, figs. 1 and 2.)

WASHING THE ROCK.

After the washing of the material by hand had been abandoned as entirely inadequate and inefficient, log washers similar to those now used in Florida[1] were introduced. The matrix in which the South Carolina phosphate is embedded, however, is of such a loose character that an elaborate cleansing process is unnecessary, so that log washers have been supplanted. By the present method the rock is scraped into a hopper, which discharges into a mechanical conveyor composed of units holding one-half ton each. It is carried to the top of the washer, where each unit of the conveyor is automatically discharged, and a stream of water washes its contents down to a crusher. From the crusher it is discharged through troughs into the lower end of several cylinder washers, which vary in number from two to eight, depending upon the size of the plant. Each cylinder is 27 feet long and 5 feet in diameter, the discharge end being 14 inches higher than the end where the phosphate material enters. The first part of the lower end and the last 2 feet of the upper end are composed of heavy wire screen, having perforations of a dimension three-sixteenths by three-fourths inch.

The interior of the cylinders is fitted with plates arranged in the form of a spiral so that they throw the phosphate forward and toward

[1] Waggaman, Bul. No. 76, Bureau of Soils, U. S. Dept. Agr. (1910).

the upper end as the cylinder revolves. A 2-inch stream of water under a pressure of 60 pounds to the square inch is played upon the phosphate material from the upper end of the cylinder. This washes the sand, clay, and finely divided phosphate down to the lower end of the cylinder where it escapes through the screen and then flows out through a trough to the wash heap, which is usually located at some distance from the plant. The washed rock falls from the upper end of the cylinder upon a rubber-coated belt 26 to 30 inches in width, along which it is carried to the wet bins. Pickers are stationed along this belt for the purpose of removing clay balls, marl, and any other foreign material which may be mixed with the phosphate. From the wet bins the rock is drawn into cars and sent to the drying sheds, where it is burned on ricks of wood. About 6 cords of wood are required to dry 100 tons of phosphate from a moisture content of 15 per cent down to a moisture content of 0.5 per cent.

COST OF PRODUCTION.

Unfortunately for the South Carolina phosphate industry, the cost of production has increased without a corresponding advance in the price of phosphate rock. Indeed, the price of this material is now so low that the smaller operators in these fields have entirely ceased mining.

The increased cost of mining is largely due to the practical exhaustion of the more accessible deposits. It is now frequently necessary to remove an overburden of 15 to 20 feet in order to uncover the phosphate stratum, where formerly there were hundreds of acres of rock lying practically at the surface or covered by only a foot or two of soil.

The price of labor has also advanced from 30 to 50 per cent, and frequently it is so difficult to obtain hands that the output of rock is seriously curtailed. The equipment of a modern phosphate plant is both elaborate and costly. Steam shovels for excavation, grab buckets and hoists for taking out the rock, many miles of steel rails, locomotives and flat cars for haulage purposes, heavy machinery for washing the rock, and large sheds for drying and storing the product are essential parts of the present mining system. (Pl. III, figs. 1 and 2.)

On account of the topography of the South Carolina coast, weather and tide conditions affect the output of phosphate rock. In rainy weather or when the tide is very high the trenches are continually filling with water, the banks caving in, and the continual use of pumps is necessary to make mining possible. The output of rock under such conditions is often cut in half, thus practically doubling the cost of mining per ton.

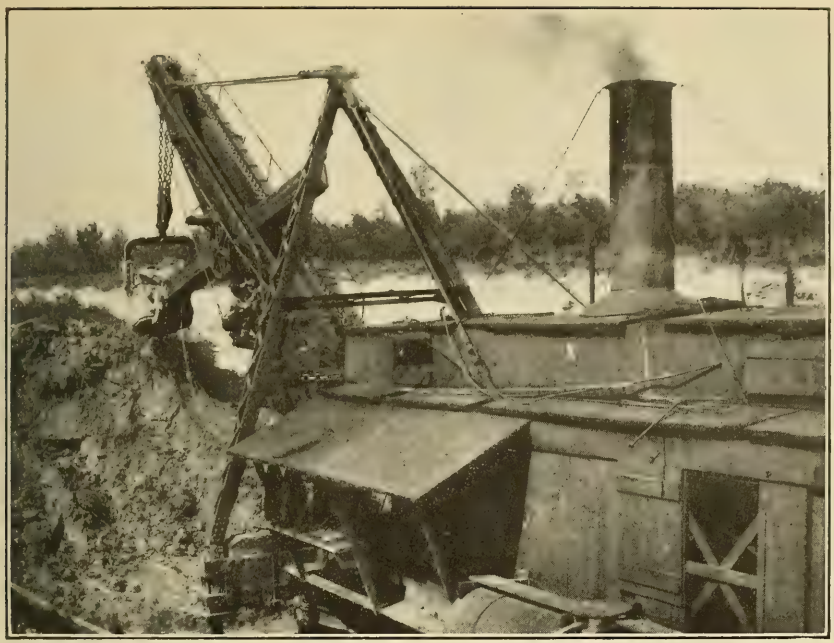

FIG. 1.—MACHINE MINING. REMOVING OVERBURDEN WITH STEAM SHOVEL.

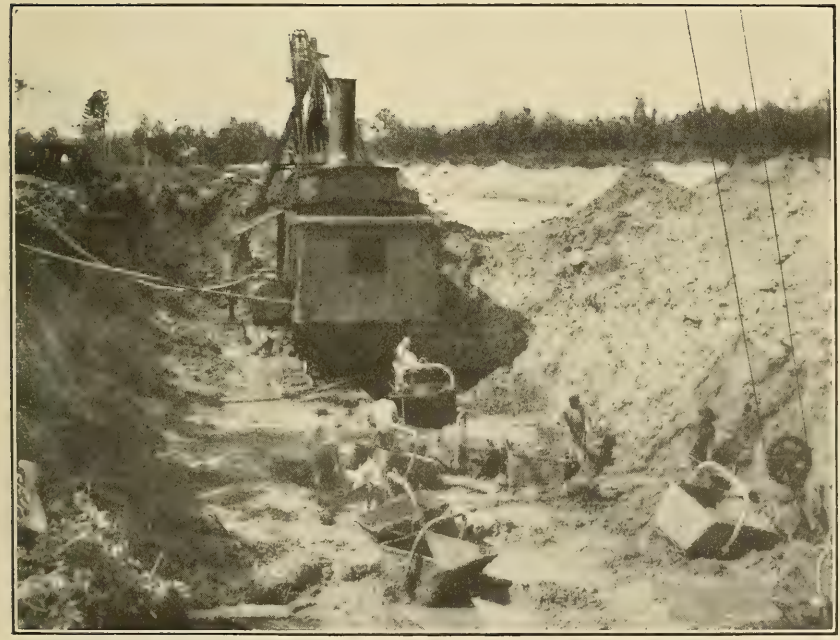

FIG. 2.—LOADING UNWASHED PHOSPHATE INTO BUCKETS TO BE HOISTED ONTO FLAT CARS.

FIG. 1.—LOAD OF PHOSPHATE READY FOR THE WASHER.

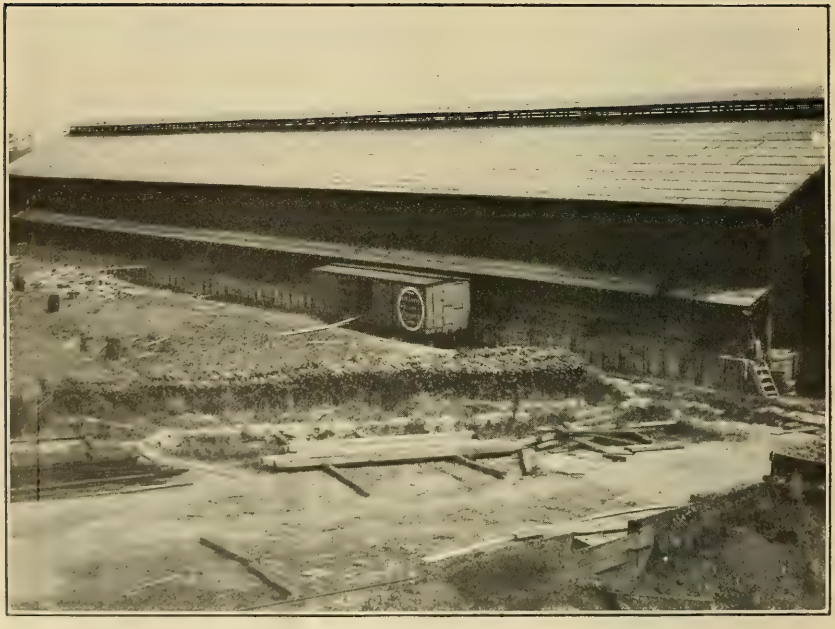

FIG. 2.—DRYING AND STORAGE SHED FOR PHOSPHATE ROCK.

These numerous and widely varying factors make it very difficult to strike an average for the cost of producing high-grade South Carolina phosphate, but the following figures, compiled from data obtained in these fields and from the author's own observation, are probably as close approximations as can be obtained.

TABLE III.—*Average cost per ton of producing South Carolina phosphate.*

Item.	Expense.	Item.	Expense.
Labor in mining	$1.50	Insurance	$0.05
Labor on washer	.10	Taxes	.05
Labor on dryer	.05	Overhead charges	.10
Haulage	.30	Depreciation	.75
Fuel for power plant	.04		
Fuel for drying rock	.12	Total	3.46
Interest on investment	.40		

WASTE MATERIAL.

In mining and preparing South Carolina rock for the market the same sources of waste are encountered as in the production of Florida phosphate. The loss of finely divided phosphate (held in suspension and passing through the cylinder screens) incident to the present method of cleaning the rock is very great, though not as great proportionally as the loss in washing the Florida product.[1] The phosphate stratum will yield on an average about 40 per cent phosphate rock; the remaining 60 per cent, consisting of sand, clay, and finely divided phosphate, is discharged upon the waste heaps. An analysis of material from the dumps made by the Bureau of Soils showed a content of about 13 per cent bone phosphate of lime, which means that over 20 per cent of the phosphate taken from the mines is discarded. Another, though minor, source of waste is at the picking board or belt where the clay balls, marl, etc., are removed by hand Inexperienced and careless pickers frequently throw away much good material.

DISPOSAL OF PRODUCT.

Although some specimens of South Carolina rock contain as high as 75 per cent of bone phosphate of lime, the average grade of the marketed product is about 61 per cent. Almost the entire output is sold in the State on a guaranty of 60 per cent of bone phosphate and made into acid phosphate by the local factories. The present price of South Carolina rock f. o. b. at the mines is about $4 per ton.

Some rock is shipped to neighboring States and a small amount as far north as Richmond, Va., but the freight rates will hardly admit of its shipment any great distance. The price of the higher grade Tennessee and Florida phosphate f. o. b. at the mines is so

[1] Waggaman, Bul. No. 76, Bureau of Soils, U. S. Dept. Agr. (1911).

much lower that they can be delivered in Charleston, S. C., at a price but little above that of the local product. Finely ground South Carolina phosphate has been tried a number of times on the soils of South Carolina and Georgia. But little success has been reported, although the increasing use of this form of phosphatic fertilizer in the Middle West indicates the desirability of further investigation.

EXTENT OF OPERATIONS.

The South Carolina phosphates (Land and River Rock) have been extensively mined in a number of localities—on both sides of the Ashley River, on the banks of the Stono River and in the stream itself, south of the Ashepoo River on Chisolms and Willimans Islands, and in the Coosaw and Beaufort Rivers.

The most productive area of Land Rock has been what is known as the Ashley River Beds, which lie on both sides of tne Ashley River, extending more or less uniformly over an area of about 200 square miles. Most of the River Rock marketed in past years was dredged from the Coosaw River, but mining operations there have been discontinued, owing to the depletion of the richer beds of phosphate and to the inability of the mining company to pay the royalty required by the State.

PRESENT CONDITION OF THE INDUSTRY.

The present condition of the phosphate industry in South Carolina is not good. The increased cost of mining, together with the low price of the product, has forced the small operator either to abandon his plant or to sell to the larger companies.

There are at present only two concerns engaged in mining South Carolina phosphate, and these are operating a total of four washer plants. The largest of these washers is at Lambs, on the Ashley River. Two smaller ones are located on the Stono River, about 9 miles west of Charleston, and the fourth is at Chisolms Island, Beaufort County. The total output of rock in 1911 was, according to the United States Geological Survey, 169,156 tons.

FUTURE OF THE INDUSTRY.

Those interested in phosphate mining are rather discouraged at the outlook in South Carolina.

There is little indication of any immediate rise in the price of rock, and the cost of preparing the phosphate for the market leaves such a narrow margin of profit that mining is only made commercially practicable by the use of up-to-date machinery capable of handling large quantities of material. Adverse weather or labor conditions decrease the margin of profit.

Contrary to general opinion, however, the South Carolina fields are far from exhausted. Thousands of acres of good phosphate land still remain unmined, and though the overburden on much of this property is rather heavy, improvements in mining methods will some day render it all available for fertilizer purposes.

An estimate of the actual quantity of phosphate still remaining in South Carolina is necessarily rough, for, though some of the lands have been thoroughly prospected, large areas have not been touched. Chazal,[1] in 1904, estimated the quantity of South Carolina phosphate still available at from 9,000,000 to 11,000,000 tons. Since that time less than 2,000,000 tons of rock have been marketed, which would leave between 7,000,000 and 9,000,000 tons. Chazal's estimate seems quite conservative, and the author is inclined to place the available tonnage somewhat higher. Suffice it to say, however, that these South Carolina fields can continue to produce rock at the present rate for many years to come.

SUMMARY.

The South Carolina phosphates were the first important deposits discovered in this country. They have been worked since 1868, and for many years produced most of our supply of phosphatic fertilizer.

The phosphate region lies along the coast in a belt extending from the Wando River, in Charleston County, to the Broad River, in Beaufort County. The rock is of Tertiary age and is usually divided into two classes, namely, the land deposits and the river deposits. These classes, however, are practically identical, the latter being merely the former washed into the river beds.

The rock is mined by first removing the overburden, either by hand or by steam shovels, and then digging out the phosphate stratum thus exposed. The rock is embedded in a matrix of sand and clay, which is removed by a washing process. During this washing much phosphate is discharged and lost in the detritus. The washed rock is afterwards dried by burning on ricks of wood.

With the exhaustion of the more accessible deposits and the discovery of higher grade phosphates in Florida and Tennessee, the output from South Carolina has fallen off considerably. River mining has entirely ceased, and only two companies are mining the Land Rock. The total output in 1911 was 169,156 tons.

The average cost of producing South Carolina phosphate for the market is about $3.46 per ton. This is so little below the present selling price of rock that the rock can not be profitably shipped. Most of it is therefore used locally in the manufacture of acid phosphate.

[1] Sketch of the South Carolina Phosphate Industry, p. 18 (1904).

The general opinion has been that the phosphates of South Carolina are practically exhausted. This is far from being the case. There are thousands of acres of rich phosphate land still practically untouched. Although the phosphate on much of this property is covered by a heavy overburden, more efficient mining methods and improved market and transportation conditions would render it all available.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 24, 1914.

(PROFESSIONAL PAPER.)

THE GRAPE LEAFHOPPER IN THE LAKE ERIE VALLEY.

By Fred Johnson, *Agent and Expert.*

INTRODUCTION.

For several years past the grape leafhopper, *Typhlocyba comes* Say (fig. 1), has been increasing in destructive numbers throughout the vineyards of the Lake Erie Valley, and since 1910 it has been recognized as a serious menace to the grape-growing interests of that region. During the years 1910 and 1911 vineyard experiments for the control of this pest were conducted by the members of the field laboratory force stationed at North East, Pa., working under the direction of Mr. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations of the Bureau of Entomology. Owing to the pressure of work involved in the conduct of numerous vineyard experiments against this pest, and also against the rose-chafer (*Macrodactylus subspinosus* Fab.) and the grape-berry moth (*Polychrosis viteana* Clem.), it was impossible to make a detailed study of the life history of the grape leafhopper during those seasons. As most of these field experiments had been brought to a successful termination at the close of the season of 1911, the investigations for the season of 1912 were devoted largely to life-history studies of this pest. In this work, which was carried on at the field laboratory at North East, Pa., the writer was assisted by Mr. E. R. Selkregg in the recording of the data bearing upon the various stages of the life history of the insect.

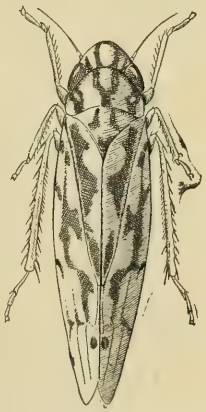


Fig. 1.—The grape leafhopper (*Typhlocyba comes*): Adult, winter form. Greatly enlarged. (Original.)

The following pages contain a record of these life-history studies, together with a short historical account of the part this insect has played as an enemy of the grapevine in other grape-producing sections of the United States and Canada. A detailed account is given

of its habits and destructiveness, the kinds of remedies that have been devised for its control, and the nature of the spray equipment and spray material which, in recent experiments, have proved most effective in holding the pest in check.

HISTORY.[1]

The first published record of this insect was made in 1825, when specimens from Missouri were described under the name *Tettigonia comes* by Thomas Say. It was next mentioned by Fessenden in 1828 as being a serious pest in Massachusetts. In 1841 T. M. Harris, in his Massachusetts report for that year entitled "Insects Injurious to Vegetation," gives a detailed description of the insect and an account of its habits, life history, and injury to the grapevine. These observations of Harris coincide quite closely with those recorded by the more recent workers who have taken up the study of this pest. Since the date of Harris's report the grape leafhopper has become increasingly prominent as a vineyard pest, and in almost all parts of this country and Canada it has, at some time or other, appeared in sufficient numbers to prove a real menace to the grape-growing industry. Although frequent mention of its injurious occurrence in many parts of the country since 1841 is to be found in entomological literature, but little original study, from an economic point of view, seems to have been bestowed upon this insect, for most of the references have the appearance of being taken from Harris's account.

During this time, however, a great variety of forms of this species had been collected, and as a result no less than six different specific names had been given it. In 1898 the subfamily Typhlocybinæ was the subject of a special study by Prof. C. P. Gillette, who worked out the synonymy of the insect as follows:

Typhlocyba comes Say, 1825.
- Variety *basilaris* Say, 1825.
- Variety *vitis* Harris, 1831.
- Variety *affinis* Fitch, 1851.
- Variety *vitifex* Fitch, 1856.
- Variety *ziczac* Walsh, 1864.
- Variety *octonotata* Walsh, 1864.
- Variety *coloradensis* Gillette, 1892.
- Variety *maculata* Gillette, 1898.
- Variety *scutellaris* Gillette, 1898.
- Variety *rubra* Gillette, 1898.
- Variety *infuscata* Gillette, 1898.

By 1897 it had become so serious a vineyard pest in California as to be placed next in destructive importance to the grape Phylloxera (*Phylloxera vastatrix* Planch.) and was the subject of a detailed

[1] The titles of papers and books, and their places of publication, are not given under this and other headings, but may be found in the Bibliography, pp. 43–47, by looking for the year indicated and, under that, for the author.

study by Prof. C. W. Woodworth. In 1901 Slingerland made a very complete study of the life history of the eastern form, *Typhlocyba comes* Say, and of remedial measures for its control, in the vineyards of Chautauqua County, N. Y., publishing the results in 1904. In 1908 Prof. H. J. Quayle conducted a similarly thorough investigation of the western form in the vineyards of California. Investigations of more recent date have been carried on in Chautauqua County, N. Y., by F. Z. Hartzell, in 1912, and by the Bureau of Entomology, United States Department of Agriculture, at North East, Pa. (See Johnson, 1911 and 1912, in Bibliography.)

ORIGIN AND DISTRIBUTION.

Since *Typhlocyba comes* and its several varieties are of common occurrence on native grapevines in the wild state almost everywhere that the grapevine is found throughout the United States and Canada, and since this species is not recorded as occurring in Europe, it is doubtless a native American species.

It was first recorded from Missouri in 1825, and since that date it has been reported as occurring in destructive numbers in nearly every State in which cultivated grapevines are grown, either in a commercial way or for home use. The following statement by Slingerland in regard to its occurrence is taken from Bulletin 215 of the Cornell Experiment Station, pages 84–85:

> In nearly all discussions of the insect enemies of the grape during the past seventy-five years, the grape leafhopper has been put in the front rank with the most destructive ones. The records show that it has deserved a prominent place in the rogues' gallery of grape pests in Massachusetts since 1828, in New York since 1856, in Illinois since 1871, in Michigan and California since 1875, in Ohio since 1888, and in New Mexico, Colorado, North Carolina and Minnesota since 1890. Destructive local outbreaks have also occurred in other States.

FOOD PLANTS.

During the growing season of the grapevine the grape leafhopper apparently confines its attacks entirely to the foliage of this plant. Early in the spring, however, before the grape leaves commence to unfold, the adult leafhoppers feed on the new foliage of almost any and all plants with which they come in contact, whether it be the foliage of trees and shrubs in woodlands or the weeds and grasses in the more open sod and pasture lands. The following is a list of trees, shrubs, and weeds the foliage of which showed evidence of feeding by the adults in the spring of 1912: Beech, maple, wild cherry, wild apple, hawthorn, dogwood, wild plum, hornbeam, hackberry, honeysuckle, wild grape, Virginia creeper, raspberry, thimbleberry, blackberry, strawberry, goldenrod, nettles, wild columbine, and a great variety of weeds and grasses. Along ravines and woodlands bordering badly infested vineyards, where large numbers of the adults

hibernate, the low-growing foliage of underbrush and shrubs will have nearly all of the green coloring matter extracted by this pest and present a whitened or sometimes brown appearance before the spring migration of the insect takes place. Those adults which winter in the vineyards feed upon the green blades and leaves of grasses, weeds, and the various plants that are grown as cover crops. When the leaves of the cultivated grapevine commence to unfold there is a wholesale migration from the foliage of the wild plants, and even from the foliage of wild grapevines, to that of the cultivated vines, amounting in the course of a week or so, from about May 10 to 25 in the region of the Lake Erie Valley, to a complete desertion of the foliage of all plants other than those of the wild varieties of grape and possibly the Virginia creeper. The percentage of hibernating adults remaining on the wild grapevines is very small compared with the number found there before the spring migration to the vineyards has taken place.

It has been observed that in seasons when the infestation throughout the vineyard area of the Lake Erie Valley has been light, some of the thinner-leaved varieties, such as Delaware and Brighton, are apparently more heavily infested and suffer more from the attacks of this pest than do the thicker-leaved varieties, such as Concord and Niagara. On the other hand, when these insects are very numerous throughout a large vineyard area but little if any difference in respect to the amount of injury to the different varieties can be observed. Usually vines of weak-growing varieties suffer most from attack by this pest, yet it has been observed, in run-down Concord vineyards in which the foliage was sparse, that reproduction of the leafhopper during the summer of 1912 was not so great on such vines, even where the overwintering adults were very numerous in spring, as in adjacent vineyards where vines of the same variety were more vigorous and the foliage was more dense.

Although many observations have been made to determine if this insect reproduces on the foliage of plants other than the wild and the cultivated grape, all the evidence secured has been of a negative nature. Attempts were made to rear nymphs on the foliage of the raspberry, which appears to be a favorite food plant of adults when they leave hibernating quarters in the spring. A large number of adults were confined in Riley cages containing raspberry plants. Although much of the foliage was whitened as a result of their feeding and many of the adults lived until about the middle of July, there was no appearance of nymphs at any time during the season upon the foliage of these plants. All observations during this investigation indicate that this insect reproduces only on the foliage of the wild and cultivated grapes, and that where vines of cultivated varieties are available it shows a preference for them and reproduces more freely upon them than upon the wild species.

CHARACTER OF INJURY AND DESTRUCTIVENESS.

The grape leafhopper injures the grapevine by attacking the foliage. It is a sucking insect in both the nymphal and adult stages and injures the plant by inserting its threadlike proboscis (fig. 2) into the underside of the leaf and extracting the juices therefrom. The result of these punctures, and more especially the removal of the juices, is first evidenced by a yellowing or whitening in patches on the upper surface of the leaf (fig. 3), which later turns brown, and finally the leaf falls from the vine prematurely. Where the injury is severe, the whole leaf dries up and becomes almost functionless long before the normal ripening period of the fruit arrives. This arrested functioning of the foliage as a result of attack by this pest has a tendency, when the injury is severe, to check the development of the entire vine, frequently to such an extent that the cane growth is considerably shortened, the size of the crop of fruit reduced, and the quality rendered inferior by a reduction of its sugar content. During very dry seasons the fruit on heavily infested vines is badly spotted by the droppings of the adult insects.

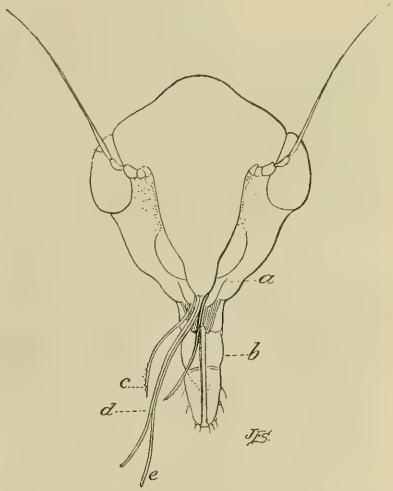


FIG. 2.—Head of grape leafhopper, showing mouthparts: *a*, Labrum; *b*, labium; *c*, mandibles; *d*, maxillæ; *e*, maxillary seta. Greatly enlarged. (Original.)

The overwintering winged adults commence to attack the new leaves of the vines when the shoots are a few inches in length. Usually the sprouts starting from the base of the vine and the new growth along the lower trellis are the first parts to be attacked. When large numbers of the adults are present feeding on this new growth, patches of yellow soon appear on the upper surface of the infested leaves, and in a short time these injured areas dry down and become brown (fig. 4), and the leaves assume a crumpled appearance, the result being a stunting of the badly infested shoots. During this time shoots higher up on the vine, being less heavily infested, have made a stronger growth which, where the vines are vigorous, soon overshadows the stunted, badly infested shoots along the lower trellis. Consequently it frequently happens that this growth on the lower trellis develops few or no long, normal, healthy canes.

This condition is of considerable importance, since it is from the healthy, well-ripened canes springing from the lower trellis that the

fruiting canes for bearing the next season's crop are selected. For the first season or two that a vigorous vineyard is infested, this stunted condition of the bearing canes is overlooked by all but the most observant vineyardists. With each additional season of heavy infestation, however, it becomes increasingly difficult to secure well-placed, robust, bearing canes, and there is a corresponding decline in the quantity and quality of the crop until in some instances the

FIG. 3.—Grape leaf showing first evidence of whitened spots resulting from feeding of adult grape leafhoppers in early summer. (Original.)

crop yield is so reduced that it pays little more than the season's cost of operating the vineyard.

OCCURRENCE AND DESTRUCTIVE OUTBREAKS.

In speaking of the occurrence of this insect Slingerland has said: "It has its periods of great destructiveness and comparative obscurity, or its 'ups and downs,' like most of our insects." It may exist on vines in limited numbers in some grape-producing section for several seasons without attracting much attention either in regard to its

presence or its injury to the foliage of the vines. During these periods serious injury to the vines or to the crop yield is confined to a few rows of vines adjacent to ravines, woodlots, or rough pasture lands. This limited amount of injury usually attracts little attention and no attempt is made by the vineyardist to hold the insect in check. Then a series of seasons favorable to its development may occur, and there appears to be a steady yearly increase in numbers and further encroachment into the infested vineyards. Finally it becomes so abundant and thoroughly disseminated throughout the vineyard

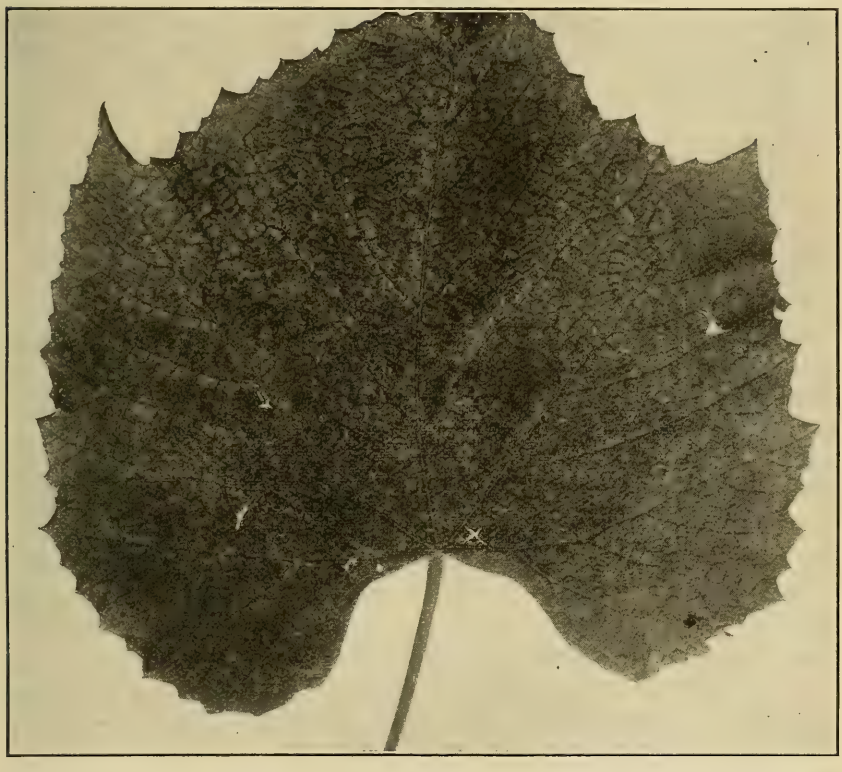


FIG. 4.—Grape leaf in advanced stages of injury. Areas between veins have turned a reddish brown. (Original.)

area, and its destruction is so obvious, that it attracts general attention, and the so-called "outbreak" causes considerable alarm among the vineyardists. Such "outbreaks" have been recorded from many States, as is indicated in the quotation from Slingerland under the caption "Origin and distribution." The same author states that "outbreaks" have occurred at frequent intervals in various parts of the State of New York as follows:

In Wyoming County in 1860; in the Hudson Valley in 1865, 1867, 1882, 1887, and 1897; on Crooked Lake in 1880; in Jefferson County in 1887 and 1888; in central New York in 1895 and 1899; and in Chautauqua County in 1900 to 1904.

During the period from 1897 to 1904 the writer of this paper resided at Westfield, N. Y., during the summer months and had the opportunity to observe the development of the outbreak of 1900 to 1904. There was not a sudden appearance of this pest in a single season, but a steady increase in numbers for several consecutive seasons preceding the so-called outbreak of 1900. On the other hand, during the summer of 1903 there was an apparent sudden disappearance of the insect from many vineyards which during the two previous seasons had been badly infested and suffered serious injury to the foliage during the seasons of 1901 and 1902. In fact, after the season of 1904 this pest disappeared from the vineyards of this area of serious infestation to such an extent that treatment was deemed unnecessary. For several years after this disappearance in destructive numbers of the insect from the vineyards in the vicinity of Westfield, N. Y., its occurrence in vineyards throughout the Lake Erie Valley was not considered of sufficient importance to warrant treatment. In 1909, however, during the conduct of vineyard experiments at North East, Pa., the appearance of this pest in injurious numbers was again observed in portions of several widely separated vineyards throughout the township. In the latter part of the season of 1910 the area of serious injury was much more widespread and its increase was viewed with alarm by vineyardists, and in the season of 1911 a number of the more progressive growers equipped themselves to fight the pest. During 1911 the injury wrought by the pest was greater than in preceding years, and the infestation was more widespread. The summer was unusually hot, and this resulted in the development of an almost full second brood which worked great injury to the vines late in the season. Immense numbers of adults went into hibernation, and large numbers of them emerged and made their appearance in the vineyards in the spring of 1912. Early in the season of 1912, on account of the presence of so many overwintering adults, there was every indication that the injury by this pest would be very great. There was an apparently normal development of the first brood of nymphs, and by the middle of the summer the injury in many vineyards was quite severe. Fortunately, however, the months of July and August were unseasonably cool. The low temperatures which prevailed during these two months so greatly retarded the development of the nymphs of the first brood that only a small percentage of the adults transforming from them deposited eggs for a second brood of nymphs. Hence there was not such a great increase in numbers of the insect during the latter end of the season of 1912 as there was at the end of the hot season of 1911. Nevertheless the injury done by this pest to many vineyards was very great. The injury to the foliage, coupled with the coolness of the summer, resulted in badly infested vineyards, in a retardation of the cane growth, in a lack of proper development of the size of the

berries in the cluster, and in a deficiency in the sugar content of the fruit. For these reasons the aggregate injury by this pest during the season of 1912 was fully as great as in that of 1911.

Thus far mention of the destructiveness of this pest has been confined to the vineyard areas of the Eastern States. For more than 25 years this species, *Typhlocyba comes*, including a western variety, *coloradensis* (fig. 5), has caused an enormous amount of injury to the grapevines in the vineyards of California, where it has been recorded as an injurious grapevine pest since 1875. Prof. H. J. Quayle, in Bulletin 198 of the California Experiment Station, states in regard to its destructiveness that "with the exception of the Phylloxera, the vine hopper is undoubtedly the most destructive insect pest of the vine in the State. It is more uniformly present than any other insect attacking the vine, and each year in some parts of the State it occurs in very great numbers, and in such sections it levies a heavy tax upon the vineyard interests."

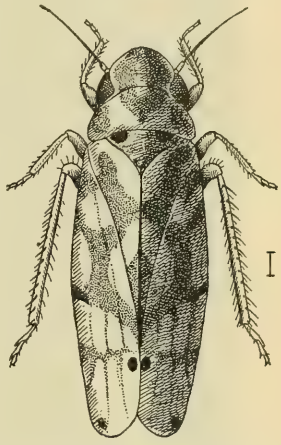


FIG. 5.—A western variety of the grape leafhopper, *Typhlocyba comes* var. coloradensis: Adult. Greatly enlarged. (Author's illustration.)

Thus it is evident that, taken in the aggregate, the injury sustained by the vineyard industry of the East and the West must amount to an enormous sum. It should be remembered, too, that the injury caused by this pest is not confined to the crop of a single season. It frequently happens that a heavy infestation of one or two seasons' duration may so stunt the growth of the vine that its full fruiting capacity may be reduced for several seasons. In fact, if special efforts for the resuscitation of badly injured vines are not undertaken they may never regain their former productive value. Hence the loss to the vineyardist not only consists in the crop shrinkage, but also in the additional cost of the fertilization and care required to get the vine back into full bearing condition.

ALLIED SPECIES.

In the region known as the Chautauqua and Erie grape belt, which includes a narrow strip of territory stretching along the southern shore of Lake Erie from Silver Creek, N. Y., to Harbour Creek, Pa., there are approximately 40,000 acres of vineyard, over 90 per cent of which are of the Concord variety. The species of leafhopper found in injurious numbers in the vineyards throughout this region is *Typhlocyba comes*. Although occasional specimens of other varieties and species may be found, their presence in numbers sufficient to

work a great amount of injury has not been observed. The other species most commonly found associated with *T. comes* is *T. tricincta* Fitch (fig. 6,*b*). This species, when present, is more likely to be found on the foliage of Delaware, Catawba, Brighton, and some of the wild species of grapevine growing along ravines or in woodlands. It is readily distinguished from *comes* by the larger size and by the fact that it has three broad black bars situated as follows: One just back of the head, another about midway across the elytra, and

FIG. 6.—The two species of grape leafhopper most common in vineyards of the Great Lakes Region: *a, Typhlocyba comes; b, Typhlocyba tricincta.* Greatly enlarged. (Original.)

the third at the tips of the elytra. Nymphs of *tricincta* (fig. 7) have two black spots back of the eyes and two on the thorax.

While making trips through the vineyard areas along the shore of Lake Erie as far west as Sandusky, Ohio, it was observed that in the Ohio vineyards east of Cleveland *Typhlocyba tricincta* was present in greater numbers than in the vineyards of Chautauqua County, N. Y., and of Erie County, Pa., although more than 80 per cent were still *Typhlocyba comes*. In the vineyards west of Cleveland *T. tricincta*

was present in greater numbers than in the vineyards east of that city. This condition also existed in the vineyards surrounding Sandusky, Ohio. In vineyards on Kelleys Island, North Bass, South Bass, and Middle Bass Islands both *T. comes* and *T. tricincta* were very abundant and there were also a number of other species and varieties in abundance which were not common in vineyards on the mainland, the most common being *T. vulnerata* Fitch. It should be stated that in the vineyards east of Cleveland, Ohio, the vines are nearly all of the Concord variety, whereas west of that city there is a considerable percentage of Catawba and of Early Ohio, while around Sandusky, Ohio, and upon the islands the percentage of the Concord variety is small, Catawba being the variety most commonly

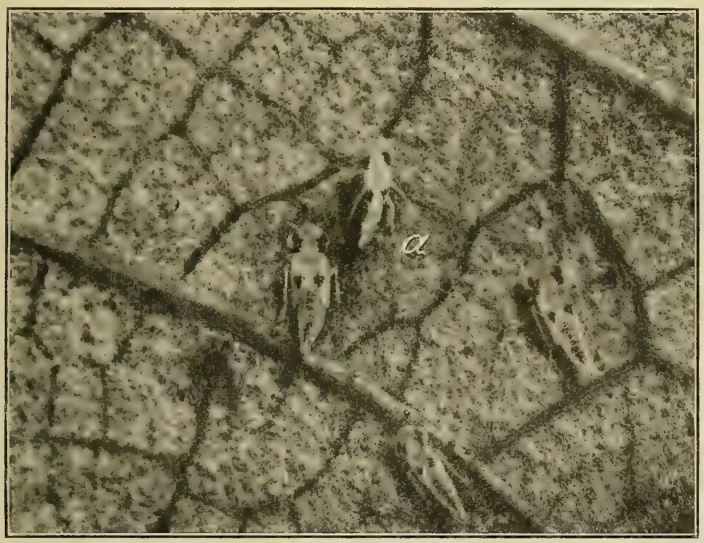


FIG. 7.—Three nymphs of *Typhlocyba tricincta* on underside of grape leaf: *a*, Cast skin of nymph. Enlarged. (Original.)

grown, as also Delaware, Ives Seedling, Elvira, and a number of other varieties used in wine making. In the vineyards on the mainland around Sandusky *T. tricincta* was the species present in destructive numbers. *T. comes* was also present, but only in small numbers.

Observations in the vineyards of Michigan during the seasons of 1911 and 1912 showed that *T. tricincta* is the predominant species in vineyards surrounding Lawton and Paw Paw and in the vicinity of Benton Harbor and St. Joseph. In the vineyards of Michigan *T. comes* is present in even smaller numbers than in the vineyards about Sandusky, Ohio.

Although the development of these two species seems to be almost identical, adults of *T. tricincta* brought from the vicinity of Dover,

Ohio, in the spring of 1912 produced a brood of nymphs which matured to adults. These adults, in turn, produced nymphs which developed to adults of the second summer brood. Observations in the vineyards of Ohio and Michigan, however, during August of 1911 and of 1912 indicate that this species produced a much smaller number of second-brood nymphs than did *T. comes* in the vineyards surrounding North East, Pa.

It should be added that a very large percentage of the grapevines grown in the Michigan vineyards are of the Concord variety, and that on these vines *T. tricincta* is the predominating species, whereas in the vineyards of the Chautauqua and Erie grape belt, where the Concord is the leading variety grown, *T. comes* is the predominant and destructive species.

Little, if any, effort has been made thus far by the vineyardists of Michigan to control *T. tricincta,* although in the season of 1911 it was quite destructive in many vineyards. Several vineyardists in the vicinity of Lawton and Paw Paw were planning to combat it with a tobacco-extract spray in 1912, but although there was a heavy infestation of overwintering adults in the spring these failed to produce a large enough brood of nymphs to injure the vines seriously, thus rendering a spray treatment unnecessary.

DESCRIPTION.

THE ADULT OR WINGED FORM.

The adult grape leafhopper (*Typhlocyba comes* Say) (see fig. 1, p. 1) is an insect about one-eighth of an inch long. The original description of the insect by Say, made in 1825 (see Bibliography), is as follows:

> Pale yellowish with sanguineous spots. Inhabits Missouri.
>
> Body pale yellowish; head, a transverse sanguineous line, profoundly arcuated in the middle, and a smaller transverse spot before; eyes fuscous; thorax with three sanguineous spots, the lateral ones smaller and the intermediate one arcuated; scutel, a sanguineous spot at tip; hemelytra yellowish white spotted with sanguineous; spots arranged two at base, of which the outer one is small and the inner one elongated and abruptly dilated on the inner side at tip; two upon the middle, of which the outer one is elongated in a very oblique line; the two behind the middle, of which the inner one is obliquely elongated, and the outer one smaller and interrupted; and a transverse linear one near the tip, ramose upon the nervures; feet whitish.
>
> Length to the tip of the hemelytra one-ninth of an inch.
>
> The line and spot on the head and the spots of the thorax are sometimes obsolete, but are always visible, and the latter are sometimes connected by curving toward the anterior edge of the thorax. The spots of the hemelytra are also sometimes slightly interrupted, or connected into four oblique bands.

In winter the color markings are deep salmon-red. After the insects have fed upon the foliage of the grapevine for a short time the color becomes paler and is displaced by a light yellow. In the

newly transformed adult these yellow markings are hardly discernible (fig. 8), the whole body being very light straw color. In a short time, however, they become more pronounced. Along toward the middle of August the salmon color begins to appear, first as a light tint on the thorax and at the base of the elytra and in a short time extending to the tips of the wings. As the season advances the salmon color deepens until the insect takes on the more pronounced red markings of the wintering adult.

THE EGG.

The eggs of the grape leafhopper are not more than three-fourths of a millimeter long and are slightly curved (see fig. 10, *d*). They are semitransparent, with a yellowish tinge, and are very difficult to locate, since they are deposited beneath the epidermis of the underside of the grape leaf, which in most varieties is covered with a heavy pubescence. It is very difficult to detect them with the naked eye even after the most careful search. They may be located, however, with the aid of a hand lens or dissecting microscope by examining the underside of the leaf in bright sunlight. Under these conditions the eggs appear as slight shiny elevations under the epidermis. By carefully scraping away the pubescence covering this area the outline of the egg may be more plainly discerned. Figure 9 is an enlarged photograph showing the outlines of two eggs beneath the epidermis of a leaf of Concord grape. The eggs are extremely delicate and are very easily crushed when an attempt is made to remove the thin, semitransparent layer of leaf skin or epidermis underneath which they have been tucked by means of the slender ovipositor of the female (fig. 11). Figure 12 shows the anal segment of a male of the same species, with its genital armature.

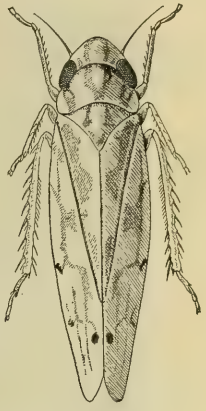


FIG. 8.—Adult grape leafhopper, summer form, showing the lighter shade of color markings of the elytra. Greatly enlarged. (Original.)

The eggs are usually deposited singly over the surface of the leaf, sometimes in or near the ribs and veins, but usually in the spaces between them. They do not appear to be placed in any regular order, but occasionally several may be found in close proximity. In one instance, in the leaf of a Clinton vine, three eggs were found quite close together with the long axis of all extending in the same general direction. Slingerland mentions finding the eggs laid from six to nine in a row in leaves of the Clinton grape. In this variety the leaf is less fleshy and has less pubescence than have the leaves of nearly all of the other varieties of grapes grown in the East. Examinations of the location and proximity of eggs in thin-leaved

species of wild grapevines did not bear out the supposition that deposition in rows is general in the thin-leaved varieties, for in all other cases where eggs were found on them they were deposited with an apparent disregard for regularity of position.

Among vineyardists there is commonly a mistaken idea that the small, transparent globules that are seen on the new growth of the grapevine, especially in the early summer, are the eggs of the grape leafhopper. These are not eggs but are small drops of sap which exude from the rapidly growing leaves and tendrils.

THE NYMPH.

The young grape leafhopper, or nymph, when it hatches from the egg, is very minute, white in color, and of the same general form as

FIG. 9.—Outline of eggs, *a* and *b*, of grape leafhopper on underside of grape leaf with pubescence pushed aside. Greatly enlarged. (Original.)

the adult, but differing from the mature parent in that it does not possess wings. It attains its growth by casting its skin in a series of five molts. These five nymphal stages are represented in Plate I. The time required for the nymph to reach maturity varies greatly with the different individuals. During the season of 1912 rearings were made of a large number of nymphs.

First stage.—The newly hatched nymph has a white body and red eyes. It does not run very rapidly at first, but moves over the underside of the leaf with rather an uncertain, "wobbly" gait. The number of days required for this stage, from hatching to the first

molt, may vary anywhere from 3 to 15. The majority of the nymphs, however, complete the stage in from 3 to 5 days.

Second stage.—In the second nymphal stage the insect becomes more active. The eyes lose some of their red color and the body assumes a yellowish tint, and at the base of the thorax there appear signs of the wing pads in the form of lateral buds. The length of this stage may vary from 1 to 7 days. The majority of nymphs complete the stage in 3 to 4 days.

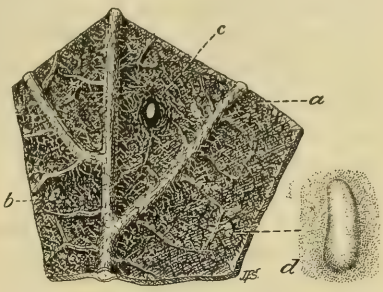


FIG. 10.—The grape leafhopper: *a* and *b*, Eggs, partially shown under pubescence; *c*, egg brought into view; *d*, greatly enlarged egg. All enlarged. (Original.)

Third stage.—The insect in the third stage moves about very actively when disturbed, running with a sidewise motion. Very rarely can one be made to hop for even the shortest distance. The red has disappeared from the eyes, and the yellow markings on the thorax have now become quite pronounced. The wing pads extend to about the caudal margin of the first abdominal segment. This stage may occupy from 1 to 11 days. In most cases from 4 to 6 days is required.

Fourth stage.—In the fourth stage the spines on the segments of the thorax and on the legs are more pronounced, and the wing pads now extend to the caudal margin of the second abdominal segment. This stage may occupy from 3 to 13 days, although the majority of nymphs complete it in 3 to 7 days.

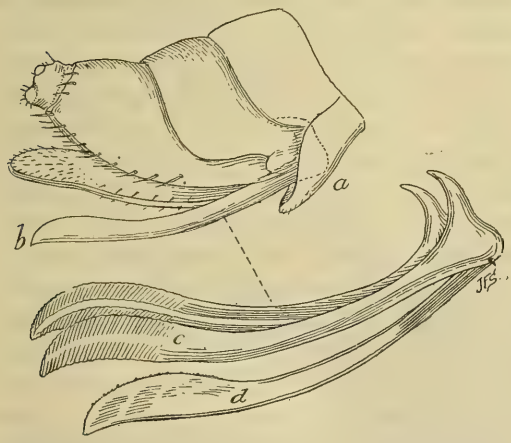


FIG. 11.—Anal segments of female grape leafhopper and details: *a*, Anal segments; *b*, ovipositor in oviposition; *c*, sheaths of ovipositor; *d*, sting. Greatly enlarged. (Original.)

Fifth stage.—In the fifth stage the wing pads are considerably lengthened, extending to about the middle of the fourth abdominal segment. The legs are much longer, and the insect runs very rapidly. This stage may cover from 4 to 20 days. The majority complete it in from 6 to 9 days.

The total length of time required to complete the nymphal stages, from hatching to the last molt, when the mature insect has fully developed wings, may vary from 19 to 37 days.

The number of days required to complete the stages of the nymph were arrived at as a result of rearing 114 nymphs through all of the five nymphal stages from hatching to adult during the season of 1912, and the data given above are based on these rearings. It was observed that variations in temperature greatly influenced the length of the different stages. It was also noted that although there might be a considerable variation in the number of days that were required by nymphs of the same age to complete any one of the stages, the total number of days covered would vary but slightly; since it frequently happened that when one stage was protracted beyond the average period, some other stage would be considerably shortened, and thus the total number of days for the entire nymphal period would be about the same for all nymphs of the same age. (See Table XI.)

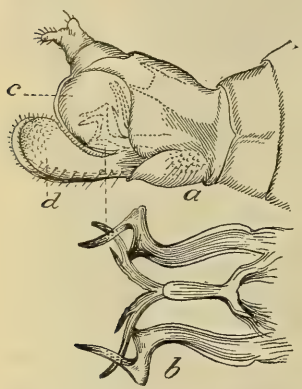
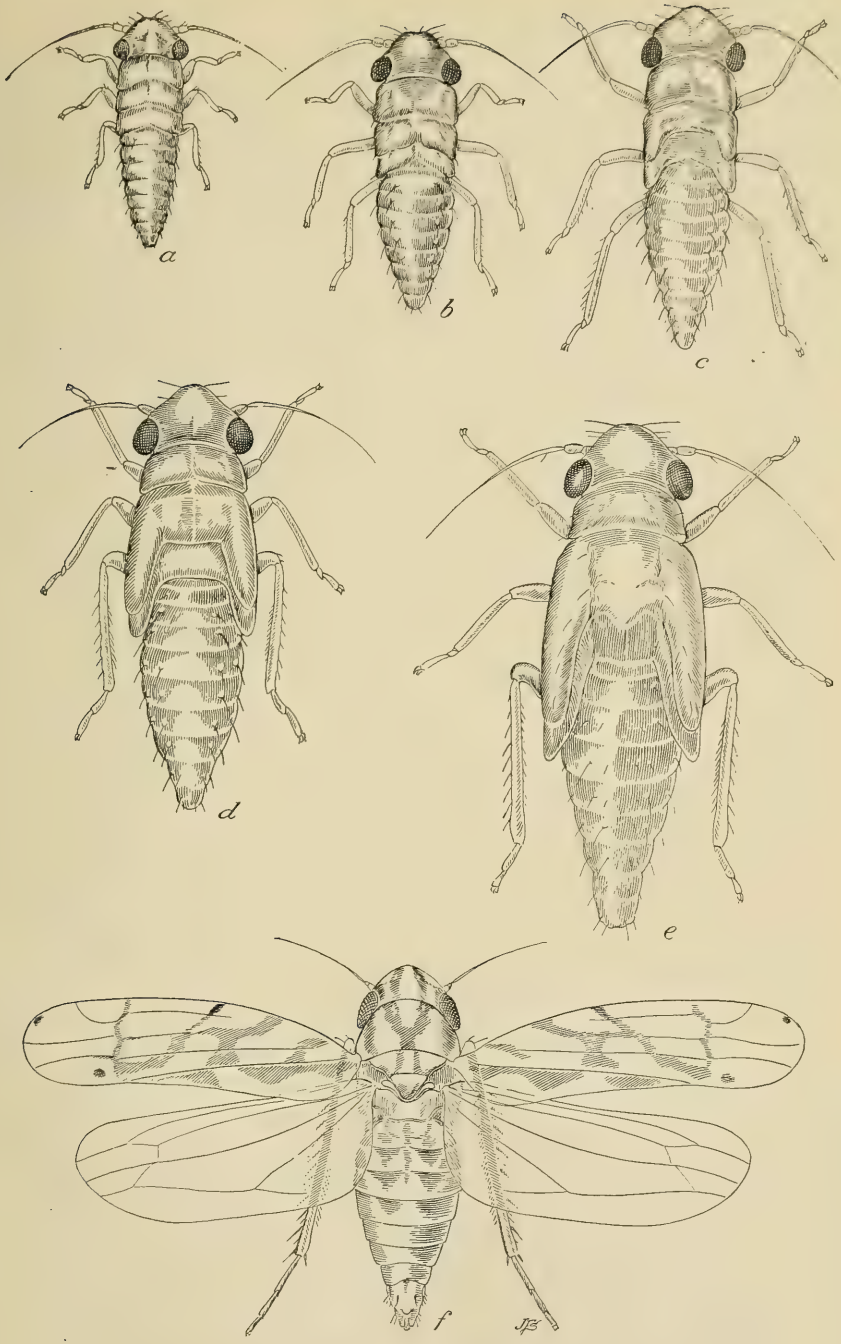


FIG. 12.—Anal segments of male grape leafhopper and details: *a*, Anal segments; *b*, genital hooks; *c*, superior clasper; *d*, inferior clasper. Greatly enlarged. (Original.)

SEASONAL HISTORY.

ACTIVITIES OF ADULTS IN EARLY SPRING.

The adult grape leafhoppers become active in their hibernating places beneath accumulations of leaves, trash, and dried grass during the warm days of late winter and early spring. During the warm sunny hours of such days they rise in swarms about one's feet when tramping through the leaves and dried grass of woodlands and swales which adjoin vineyards which were heavily infested during the preceding season. During these periods of activity they feed on the green parts of almost any plant that happens to be growing near these places of hibernation. At first the green blades of tufts of grass or the leaves of goldenrod or wild strawberry, and a little later the unfolding leaves of wild raspberry and blackberry, appear to form a favorite part of the menu offered by the woodland growth. As the days become warmer the adults extend their flight and feed upon the tender unfolding leaves of nearly all kinds of shrubs and undergrowth. When the new growth of the cultivated grapevine has attained a length of a few inches there is a general migration of the insect to the vineyards. This migration occurs about the middle of May in the vineyards of the Lake Erie Valley, and if the days are warm and bright the desertion of the woodland food plants for the foliage of the cultivated grapevine in the course of a few days is quite complete. In the spring of 1912 this migration from woodlands commenced about May 20. On May 24 the leafhoppers were extremely scarce in woodland places, where until four or five days previous they had been present in swarms since the time of first activity in spring.



THE GRAPE LEAFHOPPER.

The five nymphal stages and adult of the grape leafhopper (*Typhlocyba comes*): *a*, First stage; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, fifth stage; *f*, adult with wings spread. All greatly enlarged. (Original.)

From this date on, the adults confine their feeding and other activities to the foliage of the cultivated grapevine. About this time the red marking on the elytra disappears and is replaced by a light lemon-yellow. After the adults once settle down on the foliage of the vines in the vineyards there is very little evidence of further migration, and they seldom leave the shelter of the vines except when disturbed, in which case they fly but a short distance and return almost immediately to the underside of the grape foliage. On bright, warm days they become very active on the slightest disturbance of the vine, whereas on cold wet days it is with the greatest difficulty that they are dislodged from the underside of the leaves.

For several days after their appearance on the foliage of the grapevines the adults confine their activities to feeding on the underside of the foliage. This they do by inserting their threadlike mouth parts or proboscis into the tissue from the underside of the leaf and sucking out the juices.

TIME OF MATING.

It is exceedingly rare to find copulating pairs of adult grape leafhoppers before migration to the vineyards takes place. After migration to the vineyards mating is not common until a week or ten days of feeding has elapsed.

The first copulating pair seen during the spring of 1912 was on May 23 upon the foliage of a quince bush in the laboratory garden at North East, Pa. Occasional copulating pairs were seen in vineyards as early as May 25, 26, and 27, but mating did not appear to be general until about June 1. After June 5 mating of overwintering adults was rarely seen in the vineyards, although daily observations were made.

OVIPOSITION OF OVERWINTERING ADULTS.

No direct observation has been made of females in the act of oviposition. A number of experiments were made during the summer of 1912 to secure records of egg deposition and the number of eggs deposited by individual females, but without success. This failure was due to the fact that the leaves of all of the varieties of grapes grown in the Lake Erie Valley possess a heavy pubescence or hairy growth on the underside. This makes it extremely difficult to locate the eggs, since they are inserted within the tissue of the leaf beneath this hairy growth and can only be found after a thorough search. Even then many of them are doubtless overlooked, since it often happens that a large number of nymphs will hatch from grape leaves upon which it has been possible to locate only a small number of eggs after a prolonged and careful search. On June 10 the first eggs seen in 1912 were located on leaves of a Delaware grapevine.

LENGTH OF EGG STAGE.

Since we were unable to secure actual records of egg deposition from which to make a starting point in order to determine accurately the length of the egg stage, an approximation of this period was obtained in the following manner:

During the season of oviposition a number of adults were confined in an air-tight globe cage (Pl. II, fig. 1) upon the uninfested foliage of a small grapevine possessing not more than three or four healthy leaves. After 24 hours all the adults were removed. The vine was protected from further infestation and after seven days had elapsed was examined daily for the appearance of nymphs. A record was made of the date of the first nymphs to appear. These were removed from the cage and all other nymphs to hatch were removed at intervals of 24 hours. In the experiments recorded below the adults were placed on an inclosed grapevine, July 4, at 1 p. m. These adults were removed July 5, at 1 p. m. The newly hatched nymphs were removed on the dates recorded in Table I.

TABLE I.—*Length of incubation period of eggs of the grape leafhopper.*

Date and hour of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.
50 adults placed on vine July 4, 1 p. m.; adults removed from vine July 5, 1 p. m.		
1912.		*Days.*
July 17, 1 p. m.	6	11 to 13
July 18, 1 p. m.	46	12 to 14
July 19, 1 p. m.	58	13 to 15
July 20, 1 p. m.	7	14 to 16
July 21, 1 p. m.	5	15 to 17
50 adults placed on vine June 25, 2 p. m.; adults removed from vine June 26, 2 p. m.		
1912.		*Days.*
July 9, 2.30 p. m.	15	11 to 13
July 10, 2.30 p. m.	45	12 to 14
July 11, 2.30 p. m.	13	13 to 15
July 12, 2.30 p. m.	0	.....
July 13, 2.30 p. m.	1	15 to 17
100 adults placed on vine June 27, 2 p. m.; adults removed from vine June 28, 2 p. m.		
1912.		*Days.*
July 12, 2 p. m.	14	13 to 15
July 13, 2 p. m.	44	14 to 16
July 14, 2 p. m.	19	15 to 17
July 15, 2 p. m.	8	16 to 18
July 16, 2 p. m.	1	17 to 19
50 adults placed on vine July 27, 2 p. m.; adults removed from vine July 28, 2 p. m.		
1912.		*Days.*
Aug. 20, 2 p. m.	15	22 to 24
Aug. 21, 2 p. m.	4	23 to 25
Aug. 22, 2 p. m.	11	24 to 26
50 adults placed on vine August 10, 2 p. m.; adults removed from vine August 11, 2 p. m.		
1912.		*Days.*
Aug. 24, 2 p. m.	2	12 to 14
Aug. 25, 2 p. m.	1	13 to 15
Aug. 26, 2 p. m.	3	14 to 16
Aug. 27, 2 p. m.	0	.....
Aug. 28, 2 p. m.	0	.....
Aug. 29, 2 p. m.	2	17 to 19
Sept. 1, 2 p. m.	1	20 to 22

NUMBER OF EGGS DEPOSITED BY AN OVERWINTERING FEMALE GRAPE LEAFHOPPER.

On account of the great difficulty encountered in locating the eggs of the grape leafhopper, a record of the reproductive capacity of the females was secured by confining pairs of overwintering adults upon small grapevines in an arc-light globe cage similar to that shown in Plate II, figure 1, which had been protected from previous infestation, the object being to determine the number of nymphs that appeared on the vines. The pairs used for this purpose were among the first to be found copulating and at a period before any oviposition had taken place. Each pair of adults was allowed to remain on the vine until they died. To avoid the probability of the escape of the adults, only a few examinations were made until the nymphs were nearing the last molt. The parent adults were then removed and a careful count was made of the nymphs found upon the foliage; then the parent adults were returned to the cage until later examinations were made, and this process was continued until the death of the parent adults occurred. After the death of the adults a period equal to the length of incubation of the eggs was allowed to elapse before the final count for the last nymphs to appear was made. Four separate experiments were started May 27 with copulating pairs of adults. Removal of nymphs took place as shown in Table II.

TABLE II.—*Number of nymphs produced by a female grape leafhopper in confinement.*

1912.	CAGE NO. I.	Nymphs removed.
July 11		34
July 17		33
July 25		36
	Total	103
	CAGE NO. II.	
July 11		49
July 17		49
July 25		33
Aug. 1		8
	Total	139
	CAGE NO. III.	
July 10		[1] 4
July 11		56
July 17		34
July 25		18
Aug. 1		1
	Total	113
	CAGE NO. IV.	
July 11		34
July 17		33
July 25		36
Aug. 1		9
Aug. 2		2
	Total	114

[1] Four newly molted adults.

Several additional experiments were conducted in the same manner to determine the number of eggs per female. In each case several copulating pairs of leafhoppers were placed in each cage.

TABLE III.—*Experiment to determine extent of reproduction from four pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 19, 1912.*

1912.	Nymphs removed.
July 27	154
July 30	159
Aug. 22	8
Aug. 27	30
Aug. 29	159
Total	510
Average	127.5

TABLE IV.—*Experiment to determine extent of reproduction from nine pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 18, 1912.*

1912.	Nymphs removed.
July 24	230
July 31	423
Aug. 12	172
Aug. 22	131
Aug. 29	65
Sept. 4	14
Total	1,035
Average	115

TABLE V.—*Experiment to determine extent of reproduction from four pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 19, 1912.*

1912.	Nymphs removed.
July 24	185
Aug. 9	153
Aug. 23	58
Sept. 6	52
Total	448
Average	112

These experiments show that for 20 females the number of nymphs found ranged from 112 to 139 per female. This method of determining the egg-laying capacity of the females did not, of course, take into consideration the number of eggs that failed to hatch, or the number of fatalities which may have occurred among the nymphs after the hatching period, but the fact that the average number of nymphs reared from each of 15 females varied only from 112 to 115 would indicate that under favorable conditions a female may deposit over a hundred eggs, while the 139 nymphs obtained in cage 2 would indicate that under the most favorable conditions some females may deposit about 140 eggs.

FIG. 1.—CAGES USED FOR REARING THE GRAPE LEAFHOPPER, AT LABORATORY, NORTH EAST, PA., 1912. (ORIGINAL.)

FIG. 2.—STEAM-ENGINE POWER SPRAYER USED IN SPRAYING AGAINST THE GRAPE LEAFHOPPER, NORTH EAST, PA., 1912. (ORIGINAL.)

HATCHING OF FIRST-BROOD NYMPHS.

After the finding of eggs in the tissue of the leaves on June 10, daily examinations of infested grape foliage were made both in badly infested vineyards and on vines at the laboratory. On June 18 three nymphs were found on the badly infested foliage of a Delaware grapevine. These nymphs were probably about a day or two old, since they were slightly larger than newly hatched nymphs. They had taken on a yellowish color, which indicated that some time had been spent in feeding, for the newly hatched nymphs before having taken any food are white.

On June 20 a number of newly hatched nymphs were found on Concord vines. After June 20 the hatching of the nymphs became general. By June 26 large numbers of them could be found in all badly infested vineyards in the vicinity of North East, Pa.

The process of hatching was observed in several instances and occupies a period varying from 10 to 25 minutes.

The hatching nymph appears as a small white object projecting through the pubescence on the underside of the leaf. At first its movement is almost imperceptible. Then, after three or four minutes, there is a swaying circular movement of the free end of this white object, each succeeding movement becoming more vigorous. After four or five minutes of this rapid motion the object commences to assume a definite form. The ends of the antennæ are freed, the eyes become prominent, and the stricture dividing the thorax from the abdomen may be distinguished. In a few minutes more the proboscis and the legs may be seen moving, then the circulation of the body fluids becomes visible through the transparent skin, and finally the feet clutch the hairy pubescence of the leaf and the tiny insect draws its abdomen free of the eggshell. By this time the body has dried, and the nymph runs with a rather unsteady gait over the underside of the leaf. Usually, however, its first excursion is a very short one, for it soon settles down, inserts its minute proboscis into the leaf tissue, and makes its first meal on the juices of its host plant.

APPEARANCE OF FIRST-BROOD ADULTS.

During the season of 1912 the first evidence of the appearance of a new brood of adults occurred on July 12, when examinations of nymphs in vineyards about North East, Pa., showed that at this date an occasional nymph was making the last nymphal molt and developing wings. However, winged adults of this new brood were not common in vineyards until from July 16 to 20, and even at the latter date they did not represent more than 25 per cent of the total number of the new brood upon the foliage. In order to secure some of these earliest transforming adults for the purpose of rearing a second summer brood, about 150 of the oldest nymphs that could be found

were placed on the foliage of a young Concord grapevine on July 12. On July 13 several of these nymphs had transformed to adults. On July 16 about 75 per cent of them had developed wings.

MATING OF FIRST-BROOD ADULTS.

On July 22 numerous pairs of adults of the new brood were found copulating on the underside of grape leaves in the vineyards surrounding North East, Pa. From July 23 to 27 copulating pairs of new-brood adults were common, both in the vineyards and in cages at the laboratory. After the latter date only occasional mating pairs of adults were observed, either in the rearing cages at the laboratory or in the open vineyards, although observations along this line were continued during the remainder of the active season.

NUMBER OF EGGS DEPOSITED BY A FEMALE OF THE FIRST BROOD.

On July 26 three copulating pairs of the new-brood adults were placed in separate cages on a Concord grapevine inclosed in an arc-light globe cage similar to those in which pairs of overwintering adults had been confined, the object being to ascertain the number of nymphs that could be reared from them in order to see how it compared with the number produced by overwintering females. The number of nymphs reared from these first-brood females is shown in Table VI.

TABLE VI.—*Number of nymphs produced by a female leafhopper of the first brood.*

Date examined (1912).	Nymphs removed.
CAGE NO. I.	
Sept. 4	12
Sept. 7	5
Sept. 11	7
Sept. 14	9
Total	33
CAGE NO. II.	
Sept. 3	24
Sept. 5	16
Sept. 9	17
Sept. 11	9
Sept. 15	13
Total	79
CAGE NO. III.	
Sept. 4	37
Sept. 7	35
Sept. 11	9
Total	81

In the case of these three females of the first brood, the average number of nymphs produced by a single female was only a little more than half the number produced by the overwintering females under similar conditions.

TERMINATION OF OVIPOSITION OF ADULTS OF THE FIRST BROOD.

First-brood adults placed in cages with grapevines after August 10 gave no evidence of further reproduction, for nymphs failed to appear on the foliage. About 50 adults were placed in each of five separate cages on August 12, 15, 20, and 27, and September 9. No nymphs appeared in any of these cages, indicating that the season of egg deposition for them, at least, had closed.

Since there is a long period over which the nymphs of this first brood transform to adults, an endeavor was made to determine the date at which these later transforming adults would fail to reproduce during the same season. With this end in view, on July 24, 1912, 100 nymphs of each of the five nymphal stages were placed in five separate cages on the foliage of a small Concord grapevine in order to ascertain if the adults transforming from any or from all of the nymphs in these five cages would copulate and produce another brood of nymphs. Frequent examinations were made of all of these cages during the remainder of the season. All of the nymphs in the five cages transformed to adults, but no mating of the adults was observed nor did any nymphs of a new brood appear upon the foliage of the vines in the cages.

On the other hand, in another cage in which 50 adults were placed on July 22, to determine to what extent and how late in the season they continued to reproduce, nymphs continued to hatch as late as September 15. Below is given the daily hatching record of nymphs from these 50 adults:

TABLE VII.—*Hatching record of nymphs from 50 adult grape leafhoppers placed in confinement July 22, 1912.*

Date.	Number of nymphs removed.	Date.	Number of nymphs removed.	Date.	Number of nymphs removed.	Date.	Number of nymphs removed.
1912.		1912.		1912.		1912.	
Aug. 12	38	Aug. 22	143	Aug. 31	52	Sept. 9	25
Aug. 13	132	Aug. 23	76	Sept. 1	96	Sept. 10	13
Aug. 14	172	Aug. 24	83	Sept. 2	108	Sept. 11	8
Aug. 15	245	Aug. 25	50	Sept. 3	115	Sept. 12	6
Aug. 16	173	Aug. 26	137	Sept. 4	95	Sept. 13	4
Aug. 17	139	Aug. 27	108	Sept. 5	89	Sept. 14	2
Aug. 19	272	Aug. 28	5	Sept. 6	48	Sept. 15	6
Aug. 20	250	Aug. 29	73	Sept. 7	49		
Aug. 21	131	Aug. 30	47	Sept. 8	24		

LONGEVITY OF OVERWINTERING ADULTS.

An effort was made to determine the length of life of overwintering adults. Owing to the great activity of the adult leafhoppers it was found to be exceedingly difficult to keep a record of each individual. In order to secure some data on this point 100 overwintering adults were placed on a small Concord vine inclosed in an arc-light globe cage on May 31. A black cloth was stretched over the surface of

the ground so that the dead adults falling from the foliage of the vine might be more easily seen. An examination for dead adults was made every few days by looking for them upon the black cloth. No dead adults were observed to July 12. On July 12 the adults were transferred to a new cage to avoid confusing them with newly transforming adults. During this operation 18 adults either escaped or were killed. In this new cage 82 adults were placed. Dead adults were found in the cage on the dates shown in Table VIII.

TABLE VIII.—*Longevity of overwintering adults of the grape leafhopper.*

Date of examination.	Number dead.	Date of examination.	Number dead.
1912.		1912.	
July 17	1	Aug. 12	3
July 28	3	Aug. 17	2
Aug. 2	2	Aug. 23	4
Aug. 3	[1] 5	Aug. 27	3
Aug. 5	[2] 2	Aug. 30	5
Aug. 7	[3] 3		

[1] Escaped. [2] Killed. [3] Killed by spider.

On August 30 these adults were again transferred to a new cage to avoid their being confused with newly transforming adults. During this transfer 10 adults were either killed or escaped. In the new cage there were 39 adults. The number of dead adults found in this cage is given in Table IX.

TABLE IX.—*Longevity of overwintering adults of the grape leafhopper.*

Date of examination.	Number dead.	Date of examination.	Number dead.
1912.		1912.	
Sept. 4	4	Sept. 20	3
Sept. 7	3	Sept. 26	7
Sept. 12	1	Oct. 2	6
Sept. 14	6		

The last examination was made on October 2, when there were four adults still living. Hence it is evident that some of the overwintering adults may remain on the vines during the entire growing season. Yet in vineyards that were the object of frequent visits during the seasons of 1911 and 1912 it was observed that there was a period, about the middle of the summer each season, when a decrease in the number of hibernating adults was quite noticeable. During the season of 1911 this period of apparent decrease of overwintering adults was about June 25. In 1912 it was about July 15. In both instances this decrease in number of adults occurred about two weeks before the transformation of the new brood in large numbers to adults.

EXPERIMENTS TO REAR A THIRD BROOD OF NYMPHS.

Rearing experiments were also conducted to determine if the adults which transformed from the earliest hatching nymphs of the season would produce a second summer brood of nymphs and also if the adults transforming from these second-brood nymphs would mate and produce a third brood of nymphs.

On July 2, 100 newly hatched nymphs, the product of overwintering adults, were placed on the foliage of a Delaware grapevine inclosed in an arc-light globe cage. By July 28 a few of these nymphs had transformed to adults. By August 14 all of these first-brood nymphs had transformed to adults. On August 26 several nymphs of the second summer brood in the first two nymphal stages were found upon the foliage of the vine. On August 29 all of the adults of the first brood were removed from this cage in order that there might be no confusion with adults transforming from the second-brood nymphs. On September 12 newly transformed adults of the second brood were found in this cage. On September 27 nearly all the nymphs had transformed to adults. The few remaining nymphs were in the last nymphal stage. By October 7 all nymphs had transformed to adults. Frequent observations were made after the appearance of the second brood of adults in this cage, but no mating was observed nor did any new nymphs appear on the foliage of the vine. Hence it would appear that reproduction did not occur among the adults of the second brood during the season of 1912. A similar rearing experiment was made on July 3 by taking 75 of the earliest nymphs to hatch and placing them on a grapevine inclosed in an arc-light globe cage. By July 16 nearly all of the nymphs had transformed to first-brood adults. On August 15 new nymphs of the second brood were present. On August 28 all first-brood adults were removed from the cage. All of the nymphs transformed to second-brood adults. Although frequent examinations were made of this cage for the remainder of the season, there was no evidence of reproduction by these adults of the second brood.

In another rearing experiment the date of transformation of adults of the second brood was secured. The rearings were made by taking nymphs of the first brood that were among the earliest of the season to hatch. They were nearing the last molt when they were placed on a Concord vine in a Riley cage on July 13. By July 16 nearly all of these nymphs had transformed to adults. On July 26 several pairs were observed mating. On August 17 a few nymphs of the second brood in the first and second stages were observed on the grape foliage. On August 28 all adults of the first brood were removed from this cage to avoid confusion with newly transforming adults of the second brood. A record of the dates of transformation of adults of the second brood is given in Table X.

TABLE X.—*Transformation to adults of second-brood grape leafhoppers.*

Date of examination.	Number of adults transformed.	Date of examination.	Number of adults transformed.
1912.		1912.	
Sept. 7	1	Sept. 14	85
Sept. 8	4	Sept. 15	63
Sept. 9	0	Sept. 17	16
Sept. 10	37	Sept. 19	26
Sept. 11	76	Sept. 20	5
Sept. 12	51	Sept. 21	11
Sept. 13	51	Sept. 24	3

The last of the nymphs transformed to adults on September 24. This rearing experiment indicates that the transformation of the second-brood adults which were the progeny of the earliest nymphs of the season to appear upon the vines was much too late in the season for the production of a third brood of nymphs.

REARING EXPERIMENTS TO DETERMINE LENGTH OF NYMPHAL STAGES.

A series of rearing experiments was made to determine the length of the nymphal stages. The newly hatched nymph was placed in a cage made as follows: A hole about an inch in diameter was punched out of the center of a piece of velvet about 2 inches square. The velvet was then placed, nap side against the leaf, on the underside of an uninfested leaf. A square of heavy manila paper of the same size was placed on the upper side of the leaf directly above the square of velvet, to hold the leaf rigid. The newly hatched nymph was then placed on the underside of the leaf in the circular space cut out of the square of velvet. A small watch glass, convex side up, was placed over the circular hole in the velvet so as to overlap about one-fourth of an inch onto the velvet. Then the watch glass, the velvet, the portion of grape leaf, and the square paper were all held tightly together by means of four paper clips, by slipping on one of the clips from each side of the square, making them clasp the paper and the velvet and overlap on to the watch glass and hold the latter firmly in place so that the nymph could not escape. In some instances squares of thin sheets of celluloid were used in place of the watch glasses, but it was found that the small nymphs would sometimes drown in the moisture collecting on the inside of the celluloid. Then, too, the concave of the watch glass made the space larger. Even with the watch glasses, drowning of the nymphs was likely to occur. In order to prevent this, two squares of velvet were glued together with the nap side out. This raised the watch glass a greater distance from the leaf, giving more space between the back of the nymph and the glass, and less drowning of nymphs resulted. Each cage was examined daily; thus the condition of the nymph was observed and

record made of the date of each molt. During this operation the moisture was wiped from the inside of the watch glass.

The period covered by these rearing experiments was from June 22 to October 13. During this time 348 newly hatched nymphs were placed on grape leaves confined in cages similar to those just described. Many of the nymphs either died or escaped before they completed all of the nymphal stages. Nevertheless, complete records of the length of the five stages were secured for 114 nymphs. The greater number of fatalities occurred among the young nymphs during the early part of the rearing season before the leaf cage most suitable for the purpose was secured. After the double thickness of velvet was adopted fewer fatalities occurred.

The lengths of the several stages for the different individuals show a great variation, but it will be noted by an examination of Table XI that the variation of the total length of the five stages for a number of nymphs hatching on the same date is not very great. Changes in temperature appear to be the important factor in determining the length of time required to complete the entire nymphal period.

In the last column of Table XI the average daily temperature for the entire nymphal period of each of the 114 nymphs is given. These average temperatures are computed from the average daily temperatures given in Table XII. The average daily temperatures given in Table XII are derived from daily readings of a maximum and minimum thermometer, located in the garden of the laboratory at North East, Pa., only a few yards distant from the grapevines bearing the individual cages in which the nymphs were reared.

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912.*

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
June 22	June 28	6	June 30	2	July 4	4	July 7	3	July 11	4	19	74.90
July 5	July 9	4	July 10	1	July 13	3	July 16	3	July 25	9	20	76.60
July 9	July 12	3	July 15	3	July 20	5	July 25	5	Aug. 8	14	30	69.97
Do...	July 15	6	July 18	3	...do.....	2	...do.....	5	Aug. 7	13	29	70.10
Do...	...do.....	6	July 17	2	July 21	4	July 28	7	Aug. 8	11	30	69.97
Do...	July 12	3	July 15	3	July 20	5	Aug. 2	13	Aug. 12	10	34	70.04
Do...	July 13	4	July 16	3	July 21	5	July 27	6	Aug. 9	13	31	70.03
Do...	...do.....	4	July 17	4	July 19	2	July 25	6	Aug. 7	13	29	70.01
Do...	...do.....	4	...do.....	4	July 21	4	July 28	7	Aug. 10	13	32	70.11
Do...	...do.....	4	...do.....	4	July 19	2	...do.....	9	Aug. 9	12	31	70.03
Do...	...do.....	4	...do.....	4	...do.....	2	...do.....	9	...do.....	12	31	70.03
Do...	July 12	3	July 15	3	...do.....	4	July 25	6	Aug. 8	14	30	69.97
Do...	July 13	4	July 17	4	July 21	4	July 27	6	...do.....	12	30	69.97
Do...	July 14	5	July 18	4	July 23	5	July 29	6	Aug. 10	12	32	70.12
Do...	July 13	4	July 16	3	July 21	5	July 28	7	Aug. 9	12	31	70.03

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912*—Continued.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
July 10	July 14	4	July 18	4	July 23	5	July 30	7	Aug. 11	12	32	69.81
Do	do	4	July 17	3	July 19	2	July 25	6	Aug. 14	20	35	69.86
July 11	July 15	4	July 19	4	July 24	5	July 30	6	Aug. 12	13	32	69.58
Do	do	4	do	4	do	5	do	6	do	13	32	69.58
Do	July 16	5	do	3	July 25	6	Aug. 2	8	Aug. 13	11	33	69.69
Do	July 15	4	do	4	do	6	Aug. 1	7	Aug. 12	11	32	69.58
Do	do	4	do	4	do	6	Aug. 3	9	Aug. 13	10	33	69.69
Do	July 14	3	July 18	4	July 23	5	July 30	7	Aug. 10	11	30	69.62
July 12	July 17	5	July 20	3	July 26	6	Aug. 4	9	Aug. 13	9	32	69.75
Do	July 16	4	July 21	5	do	5	July 30	4	Aug. 15	16	34	69.32
Do	July 17	5	do	4	July 30	9	Aug. 7	8	Aug. 14	7	33	69.42
July 13	July 19	6	July 23	4	July 29	6	do	9	Aug. 15	8	33	67.14
Do	July 17	4	July 21	4	July 26	5	Aug. 2	7	Aug. 12	10	30	69.08
Do	July 19	6	July 23	4	July 29	6	Aug. 7	9	Aug. 15	8	33	69.10
July 14	do	5	July 25	6	July 30	5	Aug. 9	10	Aug. 17	8	34	68.75
Do	July 21	7	July 27	6	Aug. 4	8	Aug. 10	6	Aug. 19	9	36	68.63
Do	July 19	5	July 25	6	Aug. 1	7	do	9	do	10	37	66.77
July 15	July 22	7	do	3	Aug. 5	11	Aug. 11	6	Aug. 21	10	37	68.36
Do	July 21	6	do	4	Aug. 2	8	Aug. 10	8	Aug. 19	9	35	68.34
Do	July 20	5	July 26	6	do	7	do	8	do	9	35	68.34
July 18	July 25	7	Aug. 2	8	Aug. 8	6	Aug. 14	6	Aug. 22	8	35	67.67
Do	do	7	July 29	4	Aug. 6	8	Aug. 11	5	Aug. 20	9	33	67.79
Do	Aug. 2	15	Aug. 7	5	Aug. 9	2	Aug. 15	6	Aug. 24	9	37	67.71
Do	July 25	7	July 30	5	Aug. 8	9	Aug. 13	5	Aug. 22	9	35	67.84
July 19	July 29	10	Aug. 6	8	Aug. 11	5	Aug. 15	4	Aug. 25	10	37	67.92
Do	July 24	5	July 27	3	Aug. 3	7	Aug. 9	6	Aug. 15	6	27	68.77
Do	July 27	8	Aug. 3	7	Aug. 9	6	Aug. 15	6	Aug. 23	8	35	67.84
Do	July 26	7	do	8	do	6	do	6	Aug. 24	9	36	67.71
Do	July 25	6	do	9	do	6	Aug. 14	5	Aug. 23	9	35	67.84
Do	July 28	9	Aug. 6	8	Aug. 12	6	Aug. 15	3	Aug. 25	10	36	69.81
July 20	July 27	7	July 29	2	Aug. 3	5	Aug. 9	6	Aug. 23	14	34	67.79
Do	July 26	6	Aug. 3	8	Aug. 9	6	Aug. 14	5	Aug. 24	10	35	67.66
July 29	Aug. 8	10	Aug. 11	3	Aug. 15	4	Aug. 21	6	Aug. 31	10	33	67.53
Do	Aug. 7	9	do	4	Aug. 17	6	Aug. 22	5	Sept. 1	10	34	67.73
Do	Aug. 5	7	Aug. 10	5	Aug. 14	4	Aug. 21	7	Aug. 29	8	31	69.03
Do	Aug. 7	9	Aug. 11	4	Aug. 15	4	do	6	Aug. 30	9	32	67.84
Do	Aug. 8	10	Aug. 12	4	Aug. 16	4	Aug. 22	6	Sept. 1	10	34	67.73
Do	Aug. 6	8	Aug. 11	5	do	5	do	6	do	10	34	67.73
July 30	Aug. 11	12	Aug. 14	3	Aug. 20	6	Aug. 25	5	Sept. 3	9	35	68.16
Do	Aug. 7	8	Aug. 11	4	Aug. 15	4	Aug. 21	6	Aug. 30	9	31	67.68
Do	Aug. 9	10	Aug. 14	5	Aug. 19	5	Aug. 25	6	Sept. 2	8	34	67.95
Do	do	10	Aug. 12	3	Aug. 17	5	Aug. 22	5	Sept. 1	10	33	67.68
Aug. 5	Aug. 11	6	Aug. 15	4	Aug. 20	5	Aug. 25	5	Sept. 5	11	31	69.95
Do	do	6	do	4	do	5	do	5	Sept. 3	9	29	68.55
Aug. 13	Aug. 19	6	Aug. 23	4	Aug. 27	4	Sept. 2	6	Sept. 8	6	26	71.52
Do	Aug. 18	5	do	5	do	4	Aug. 29	2	Sept. 9	11	27	71.41
Do	Aug. 21	8	do	2	Aug. 29	6	Sept. 3	5	Sept. 10	7	28	71.55
Do	Aug. 18	5	Aug. 22	4	Aug. 26	4	Sept. 2	7	Sept. 8	6	26	71.52
Aug. 14	Aug. 20	6	Aug. 25	5	Aug. 31	6	Sept. 4	4	Sept. 11	7	28	71.75
Do	Aug. 19	5	Aug. 24	5	Aug. 28	4	Sept. 3	6	Sept. 9	6	26	71.33
Do	Aug. 20	6	do	4	Aug. 29	5	Sept. 5	7	Sept. 10	6	27	71.48
Do	do	6	do	4	Aug. 28	4	Sept. 4	7	Sept. 11	7	28	71.75
Do	do	6	do	4	do	4	Sept. 3	6	Sept. 9	5	26	71.33
Do	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 2	6	Sept. 8	6	25	71.44
Do	Aug. 20	6	Aug. 24	4	Aug. 29	5	Sept. 3	5	Sept. 9	6	26	71.33
Do	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 2	6	do	7	26	71.33
Do	Aug. 20	6	Aug. 25	5	Aug. 29	4	Sept. 3	5	do	6	26	71.33
Do	do	6	Aug. 26	6	Sept. 2	7	Sept. 6	4	Sept. 14	8	31	71.24
Do	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 3	7	Sept. 9	6	26	71.33
Do	Aug. 24	10	Aug. 29	5	Sept. 2	4	do	1	Sept. 10	7	27	71.48

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912*—Continued.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	*° F.*
Do	Aug. 20	6	Aug. 25	5	Sept. 1	7	Sept. 4	3	Sept. 10	6	27	71.48
Do	do	6	Aug. 24	4	Aug. 29	5	Sept. 3	5	Sept. 9	6	26	71.33
Do	do	6	Aug. 25	5	Sept. 1	7	do	2	Sept. 10	7	27	71.48
Do	do	6	Aug. 24	4	Aug. 27	3	Sept. 2	6	Sept. 9	7	26	71.33
Aug. 15	Aug. 23	8	Aug. 26	3	Aug. 31	5	Sept. 4	4	Sept. 10	6	26	71.57
Do	Aug. 21	6	do	5	do	5	do	4	do	6	26	71.57
Do	do	6	do	5	Aug. 30	4	do	5	do	6	26	71.57
Do	do	6	do	5	Aug. 31	5	do	4	do	6	26	71.57
Do	do	6	Aug. 25	4	Aug. 30	5	do	5	Sept. 9	5	25	71.42
Do	do	6	do	4	do	5	Sept. 2	3	Sept. 10	8	26	71.57
Aug. 16	do	5	do	4	do	5	Sept. 3	4	do	7	25	71.80
Do	do	5	do	4	Aug. 31	6	Sept. 4	4	do	6	25	71.80
Aug. 17	do	4	Aug. 26	5	Sept. 1	6	do	3	Sept. 11	7	25	72.40
Do	Aug. 22	5	do	4	Sept. 2	7	Sept. 5	3	do	6	25	72.40
Do	do	5	do	4	Sept. 1	6	do	4	do	6	25	72.40
Do	do	5	Aug. 27	5	do	5	do	4	do	6	25	72.40
Aug. 20	Aug. 25	5	Aug. 30	5	Sept. 3	4	Sept. 6	3	Sept. 13	7	24	76.58
Do	Aug. 24	4	Aug. 27	3	Sept. 2	6	Sept. 5	3	Sept. 11	6	22	73.20
Aug. 21	Aug. 25	4	Aug. 30	5	Sept. 3	4	Sept. 6	3	Sept. 12	6	22	72.95
Do	do	4	Aug. 29	4	Sept. 2	4	do	4	Sept. 13	7	23	72.65
Do	Aug. 26	5	Sept. 1	6	Sept. 4	3	Sept. 7	3	Sept. 14	7	24	72.66
Do	Aug. 25	4	Aug. 29	4	Sept. 2	4	Sept. 6	4	Sept. 12	6	22	73.18
Do	Aug. 26	5	Sept. 1	6	Sept. 4	3	Sept. 7	3	Sept. 14	7	24	72.66
Do	Aug. 25	4	Aug. 31	6	Sept. 3	3	Sept. 6	3	Sept. 13	7	23	72.65
Do	Aug. 26	5	do	5	do	3	Sept. 7	4	Sept. 15	8	25	72.74
Aug. 22	Aug. 27	5	Sept. 2	6	Sept. 5	3	Sept. 8	3	do	7	24	72.83
Do	Aug. 26	4	Aug. 31	5	Sept. 3	3	Sept. 7	4	Sept. 14	7	23	72.78
Do	do	4	Sept. 1	6	Sept. 4	3	do	3	Sept. 15	8	24	72.83
Do	do	4	do	5	do	3	do	3	Sept. 14	7	25	72.78
Aug. 30	Sept. 3	4	Sept. 7	4	Sept. 9	2	Sept. 13	4	Sept. 22	9	23	72.50
Sept. 4	Sept. 7	3	Sept. 14	7	Sept. 15	1	Sept. 22	7	Oct. 6	14	32	65.01
Do	do	3	Sept. 12	5	do	3	Sept. 23	8	Oct. 8	15	34	64.41
Do	do	3	Sept. 11	4	Sept. 14	3	Sept. 20	6	Oct. 6	16	32	65.01
Sept. 6	Sept. 10	4	Sept. 14	4	Sept. 19	5	Sept. 25	6	Oct. 12	17	36	63.64
Do	do	4	do	4	Sept. 18	4	do	7	do	17	36	63.64
Do	do	4	do	4	Sept. 19	5	do	6	do	17	36	63.64
Do	do	4	do	4	do	5	Sept. 24	5	Oct. 10	16	34	63.53
Do	do	4	Sept. 13	3	Sept. 18	5	Sept. 25	7	Oct. 13	18	37	63.32
Do	do	4	Sept. 14	4	do	4	do	7	do	18	37	63.32

TABLE XII.—*Maximum, minimum, and average temperatures taken at the field laboratory, North East, Pa., from June 1 to October 31, inclusive.*

Day of the month.	June.			July.			August.			September.			October.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1	70	50	60.0	72	53	62.5	66	52	59.0	84	65	74.5	57	49	53.0
2	78	64	71.0	75	58	66.5	69	53	61.0	86	68	77.0	64	45	54.5
3	77	59	68.0	82	68	75.0	63	64	63.5	81	69	75.0	70	54	62.0
4	76	60	67.5	83	68	75.5	65	49	57.0	79	69	74.0	67	56	61.5
5	69	44	56.5	84	68	76.0	65	54	59.5	87	68	77.5	70	51	60.5
6	67	54	60.5	84	70	77.0	70	50	60.0	84	69	76.5	77	54	65.5
7	68	46	57.0	92	72	82.0	71	55	63.0	86	70	78.0	69	49	59.0
8	59	38	48.5	87	71	79.0	78	54	66.0	77	56	66.5	58	43	50.5
9	66	45	55.5	85	73	79.0	78	66	72.0	77	62	68.5	71	51	61.0
10	65	58	61.5	80	72	76.0	78	67	72.5	83	68	75.5	67	56	61.5
11	70	55	62.5	87	69	78.0	76	63	69.5	89	69	79.0	73	50	66.0
12	78	60	69.0	85	66	75.5	76	61	68.5	74	58	66.0	74	54	64.0
13	68	49	58.5	82	65	73.5	80	67	73.5	76	54	60.5	59	46	52.5
14	61	48	54.5	87	69	78.0	79	59	69.0	78	68	73.0	59	45	52.0
15	78	60	69.0	83	73	78.0	69	63	66.0	80	69	74.5	55	44	49.5
16	72	57	64.5	92	61	76.5	72	56	64.0	82	60	71.0	55	39	47.0
17	77	57	67.0	74	63	68.5	67	53	59.5	62	49	55.5	63	46	54.5
18	69	50	59.5	77	63	70.0	69	64	66.5	69	59	64.0	71	56	63.5
19	65	48	56.5	82	57	69.5	78	67	72.5	73	60	66.5	63	52	57.5
20	64	57	60.5	65	52	58.5	71	63	67.0	69	54	61.5	54	45	49.5
21	71	57	64.0	75	63	69.0	75	65	70.0	68	57	62.5	71	48	59.5
22	67	59	63.0	77	63	70.0	76	60	68.0	79	63	72.0	65	56	60.5
23	69	49	49.0	73	54	63.5	75	65	70.0	77	56	66.5	56	43	49.5
24	70	50	60.0	72	60	66.0	69	57	63.0	62	55	58.5	44	41	42.5
25	74	65	69.5	70	68	69.0	80	71	75.5	69	61	65.0	48	44	46.0
26	80	61	70.5	75	61	68.0	82	66	74.0	78	61	68.5	54	44	49.0
27	78	58	68.0	75	52	63.5	82	58	70.0	64	47	55.5	56	41	48.5
28	82	67	74.5	70	57	63.5	62	52	57.0	56	43	48.5	60	47	53.5
29	77	64	70.5	75	64	69.5	59	54	56.5	63	47	55.0	70	55	62.5
30	83	59	71.0	73	57	65.0	67	48	57.5	51	36	43.5	63	64	54.5
31				72	52	62.0	63	59	61.0				54	44	49.0

SUMMARY OF SEASONAL HISTORY OF THE GRAPE LEAFHOPPER.

The grape leafhopper (see fig. 1, p. 1) hibernates as an adult among accumulations of leaves and trash in vineyards, but mostly in adjoining woodlands, hedgerows, and pastures. It becomes active during the first warm days of spring and commences feeding on the new growth of almost any of the plants with which it comes in contact. With the unfolding of the grape leaves there is a general migration of the insect to the vineyards. In normal seasons this takes place about the middle of May in the vineyards of the Lake Erie Valley. After feeding for a few days the leafhoppers mate, and oviposition commences early in June. The eggs are deposited singly and are tucked under the epidermis beneath the pubescence of the underside of the grape leaf. The average length of the egg stage is from 11 to 15 days. The nymphs commence to appear on the underside of the leaves about the 20th of June, and by the end of the first week in July a large percentage of the first brood has hatched and is present in one of the several nymphal stages,

of which there are five. (See Pl. I.) The average length of the nymphal period is about 28 days, but with many it varies from 20 to 35 days. At the last nymphal molt the adults have fully developed wings. A few newly transformed adults may be found in vineyards from about July 7 to July 12.

In normal seasons, however, the majority of the first-brood adults appear after the middle of July. Observations of the development of the insect indicate that if the nymphal period is lengthened by low temperatures during the month of July, the number of adults of the new brood that will mate and deposit eggs for a second brood is quite small; whereas, if high temperatures prevail during the early part of July, a large number of the nymphs are likely to develop rapidly and make their transformation about the middle of July. These early maturing adults mate and deposit eggs, and the resulting second brood of nymphs is quite large.

Mating of the first-brood adults appears to be common for only a few days. In 1912 few mating pairs were seen except during the period from July 23 to July 27.

Early in August the color markings on the elytra of the adults change from light yellow to a pale salmon color, which becomes more intense as the season advances. After the appearance of this change in coloration of the elytral markings little oviposition occurs.

By the early part of September most of the nymphs of both the first and second broods have transformed to adults, although a small number of nymphs may be found on the foliage until quite late in the fall. Toward the middle and latter part of September the adults commence to migrate from the vineyards and during warm, calm afternoons may be seen in swarms drifting through the air in an apparently aimless manner. They usually come to rest in adjoining woodlands or rough pasture lands. Here they remain more or less active during the warmer parts of the days of October and the late fall, seeking the shelter of leaves and trash at night and during the cooler days, and becoming less active as the cold weather of winter approaches.

REARING CAGES USED.

Since the adult grape leafhoppers are very agile creatures it was impossible to study their habits and life history in detail on the large fruiting vines in the open vineyard. Yet in order that the adults might oviposit and the eggs develop normally, it was necessary that the insects studied should be confined on healthy growing grape foliage. For this purpose a large number of young grapevines, including several varieties, were planted in the garden of the laboratory early in the spring of 1912. The vines were planted in rows about 3 feet apart. Those vines used for securing egg records,

longevity of overwintering adults, number of eggs deposited per female, length of nymphal stages, etc., were covered with a cage early in the season so as to prevent the foliage from becoming infested by other adults.

Since it was impossible to secure enough Riley cages, or to have cages made that were sufficiently tight to prevent the escape of the adults, recourse was taken to the use of a number of second-hand arc-light globes, which were secured from the local lighting plant. These were about 15 inches high, with a small opening about 4 inches in diameter and a large opening about 8 inches in diameter. The globe was placed over the vine with the lower opening resting on the ground, and the larger opening was covered with a piece of muslin fastened to a stout wire ring. This cover was drawn tightly over the large opening by means of four cords fastened to the wire ring and connected to four pegs driven into the ground and tightened in the same manner as are the cords of a tent. In this way it was possible to draw the muslin perfectly tight all around the edge of the upper opening of the globe. The insects were examined during the cooler part of the day when they were least active. It was found that when the lower opening was set into the ground, the temperature inside of the cage was several degrees higher than that on the outside, owing to a lack of circulation of air inside the cage. This was overcome by taking a strip of fine wire screen about 4 inches wide and forming it into a collar a little larger than the smaller opening of the globe. This collar was then slipped over the young grapevine and pressed firmly into the soil. The globe was then placed over the vine and the small opening fitted into the wire screen collar, thus securing an air current into the bottom of the cage up through the muslin cover or vice versa. The muslin cover was then made large enough to shade the greater part of the globe. These modifications resulted in securing a cage that was light and tight, and that had a temperature about the same as that on the outside.

The cage that has just been described (see Pl. II, fig. 1) is spoken of as an "arc-light globe cage" in connection with the rearing experiments mentioned under seasonal history.

A smaller cage, employed for rearing single nymphs for the purpose of recording the length of the stages of individuals, is fully described on page 26 under another caption dealing with experiments to determine the length of the nymphal stages.

PARASITES AND PREDACEOUS ENEMIES.

Apparently the grape leafhopper suffers little from the attack of parasitic enemies. No records of parasites have been found in the literature dealing with this pest. During the investigations on grape insect pests conducted at North East, Pa., from 1907 to 1912, only

one instance of parasitism was noted. In this instance, on July 31, 1907, Mr. P. R. Jones, of the Bureau of Entomology, observed the female of *Aphelopus* sp. in the act of thrusting her ovipositor into the body of a nymph. No attempt was made to determine if eggs were deposited in the body of this nymph, nor was any further evidence of parasitism of the nymphs or the adults of the grape leafhopper observed.[1]

On the other hand, the nymphs seem to be especially subject to the attack of many predaceous insects, mites, and spiders, while the adults become entangled in spider webs and are preyed upon by the occupants.

FIG. 13.—Adult grape leafhopper parasitized by a dryinid, and showing cocoon of parasite protruding from abdomen, at left. Greatly enlarged. (Original.)

The literature on the grape leafhopper contains the following records of attack by predaceous enemies on either the nymphs or the adults:

B. D. Walsh, in 1862, records *Hemerodromia superstitiosa* Say, one of the dance flies, as feeding on the "hoppers" in Illinois.

Townend Glover, in 1875, records *Hyaliodes vitripennis* Say, the glassy-winged soldier-bug, as feeding on the nymphs.

M. V. Slingerland, in 1902, records a mite, *Rhyncholophus parvulus* Banks, the larvæ of Chrysopa, and aphis lions as feeding on the nymphs.

J. H. Quayle, in 1908, records the destruction of the nymphs by the beetles and larvæ of ladybirds, aphis lions, and ants, but states that all of these predaceous enemies put together have little apparent influence in lessening the number of the pest.

During the investigation of this pest at North East, Pa., aphis lions, ants, mites, and spiders were frequently observed preying upon the nymphs, and in addition to them a very active orange-colored mite (*Anystis agilis* Banks) was often found feeding upon the nymphs and occasionally upon the adults, especially just after the latter had transformed and had not the full use of their wings. Both the nymph and the adult of a capsid of the genus Diaphnidia near *D. hamata* Van Duzee were frequently found with nymphs of *T. comes* impaled on their long probosces. Yet all of these predaceous enemies combined failed to have any appreciable influence in reducing the destructive numbers of the leafhopper.

[1] While Mr. J. F. Strauss, of this bureau, was making drawings of adults of *T. comes* for this paper he found an adult among some material in alcohol with the pupa of a dryinid (see fig. 13) attached to the body. These specimens were collected by the writer in vineyards near Euclid, Ohio, Aug. 9, 1911.

NATURAL CHECKS.

It would seem, however, that there are some as yet unknown natural checks which greatly reduce the numbers of this insect and occasionally almost entirely eliminate it over areas where only a short time previously it had been a serious pest.

In 1865 Trimble observed that once when the thermometer reached 100° F. thousands of the "hoppers" were killed.

There was a great diminution in numbers of the adults in the infested area of the Chautauqua County vineyards early in the season of 1903.

A condition similar to this was observed by Mr. E. W. Scott, of the Bureau of Entomology, during the season of 1912, when adults of *Typhlocyba tricincta* were so very abundant in the vineyards near Benton Harbor, Mich., that the vineyardists became greatly alarmed, many of them making preparations to spray the nymphs when they should appear. Yet this proved unnecessary, for when the time arrived for the nymphs to appear upon the foliage in large numbers most of the adults had disappeared and very few nymphs of the new brood had hatched. As yet nobody appears to be able to account for these sudden disappearances of the pest or to determine whether they are due to climatic or other causes.

In September, 1890, Thaxter observed that in Connecticut grape leafhoppers in large numbers were injuring a vineyard. He found that they were attacked by a fungous disease (*Empusa* sp.) which apparently destroyed all of them. This is the only case on record in which this insect was attacked by a fungous disease. Nothing of this nature has been observed in the vineyards of the Lake Erie Valley during the present investigation, and for the past four or five seasons the pest has steadily increased. Probably the time may not be far distant when large numbers of them will suddenly disappear, as happened at Westfield, N. Y., in the season of 1903. However, it is by no means safe for the vineyardist to count on these natural checks, for while one is waiting for relief from such a source the pest may work incalculable damage to his vineyard.

REMEDIES.

During the period that this insect has attracted the attention of economic entomologists much experimental work has been undertaken to determine the most effective means for its control. Early in the control work undertaken against this pest, tobacco, in some form or other, was employed as a killing agent. In 1828 Fessenden (see Bibliography) recommended the smoking of infested vines by burning tobacco stalks beneath them.

In 1843 J. F. Allen (see Bibliography) advised syringing or spraying infested vines and also smoking them by burning tobacco stalks. Since this date the use of tobacco in both of the forms mentioned has occupied a prominent place among substances recommended for the control of the grape leafhopper. The former method, that of fumigation, however, was impracticable for the open vineyard. In fact, it is quite probable that the process of fumigation with tobacco was originally intended for use against the insect when found infesting grapevines growing in hothouses which could be closed during the period of treatment. On the other hand, the use of a liquid tobacco decoction has withstood the test of numerous experiments in comparison with a large number of liquid spray materials and at the present time is the insecticide most generally recommended in making spray applications against the nymphs.

In the following paragraphs is presented a list of substances and mechanical methods either experimented with or recommended by various entomologists (see Bibliography) since this insect has been a pest of economic importance:

Liquid sprays.—Syringing with tobacco water or soapsuds (W. Saunders, 1870). Spraying with carbolic acid (W. L. Devereaux, Rural New Yorker, 1883). Spraying with kerosene and water, or sheep dip (O. Lugger, 1896). Spraying the adults with kerosene and water and the nymphs with whale-oil soap (M. V. Slingerland, 1904).

Dust sprays.—Dusting with lime and sulphur (C. J. S. Bethune, 1868). Dusting with hellebore (W. Saunders, 1870).

Other mechanical methods.—The use of sticky shields to trap the adults; torches to attract the adults (C. V. Riley, 1873). Destruction of leaves to destroy adults in hibernation (A. J. Cook, 1875). Sticky shields and cloth wet with kerosene to trap adults (J. A. Lintner, 1887). Sheets of cardboard smeared with tar to trap adults (F. M. Webster, 1893). Burning of leaves and rubbish in and surrounding vineyards to destroy adults in hibernation (O. Lugger, 1896). Sticky fans to catch adults as they fly from vines; collecting nets to catch adults (C. W. Woodworth, 1897). Box or cage having inside smeared with a sticky substance; the cage is placed over the infested vine and the "hoppers" are caught on the sticky sides and bottom of the cage (H. J. Quayle, 1908). Sticky shields held on both sides of the trellis (M. V. Slingerland, 1904).

Many of the methods of control mentioned in the foregoing paragraphs have been recommended by various other authors treating this subject. The foregoing simply indicate the date of their first mention in literature.

In his experimental work in vineyards in Chautauqua County, N. Y., Slingerland carried on quite extensive experiments with sticky shields for catching the adults before the commencement of egg deposition, the most practical shield for trellised vineyards being constructed and used as follows:

Make a light wooden frame about seven or eight feet long and four feet wide, having the bottom crosspiece about a foot from the ground and fasten to this stiff wires extending down nearly to the ground and bent inward something like hay-rake teeth. Tack over this a strip of table oilcloth 1¼ yards wide and let it extend down over the

curved wire teeth, so that when the shield is held beside a vine, the oilcloth will come under the vine to catch the "hoppers" that try to drop to the ground. Cover the oilcloth with the "stick-em" and all is ready to operate. Two men, each carrying one of these light sticky shields on opposite sides of a trellis of vines, can reach over the shields, jar the vines to disturb the "hoppers" and thus go over an acre of vineyard in a little more than an hour.

In California, where the vines are not trained to a trellis, Mr. Quayle found that a screen cage having the inside smeared with crude oil, with one side open and a V-shaped opening cut in the bottom to admit the stem of the vine, could be used quite effectively in the vineyards to catch the adults before egg deposition commenced. In the course of his field experiments in California Mr. Quayle conducted experiments with suction apparatus for collecting the adults from the vines. He also attempted to destroy them with torches; by the application of dry powders, including lime, hellebore, and dry sulphur; and also by the fumigation of infested vines, both with cyanid and sulphur gas. None of these latter methods gave results of a practical nature, and the only mechanical method of control against the adults recommended by him is that of the screen cage previously mentioned.

Destruction of leaves and trash.—Many authors have urged the destruction of leaves and trash in and adjoining infested vineyards, while the insects are in hibernation, as a means of lessening their numbers. However, since the adults rise in the air and either fly or are carried considerable distances by the winds during the migrations which take place during the spring and fall, there are usually large areas of wood lots and pasture lands at considerable distances from vineyards where swarms of the adults may be found during the winter. Since in many cases these areas of rough land are not controlled by the owners of the vineyards there is slight possibility that this cleaning-up process will be undertaken on a large enough scale to be of any great value in lessening the numbers of overwintering adults. Furthermore, at the present time there is a strong tendency toward the growing of some form of cover crop, such as clover, vetch, turnips, rye, oats, etc., in vineyards as a means of furnishing soil protection and fertility; and this is very necessary and desirable in most of the vineyards of the Lake Erie Valley. This would have to be abandoned if the clean-culture method were followed. Observations along this line covering several seasons indicate that where cover crops are growing in badly infested vineyards the number of adult grape leafhoppers found among the shelter thus afforded is generally very small compared with the number that have migrated to adjacent wood lots and rough pasture lands. In fact, it would appear that there is a tendency for the larger percentage of adults to migrate from the vineyards in the fall, and this migration appears to be their chief mode of dispersal as much as a means for securing suit-

able hibernating quarters. Hence too much should not be expected of this destruction of leaves and trash on a limited scale, since in the following spring the adults are likely to swarm back into the vineyards from areas not included in the cleaning-up process.

SPRAY TREATMENT.

During recent years a great deal of attention has been given to combating this pest by means of liquid sprays. Owing to the agility of the winged adults, and also to the fact that their sloping wing covers protect their soft bodies from the killing action of spray liquids not sufficiently caustic to injure the foliage of the grapevines, it is a very difficult task to destroy many of them with liquid spray applications. This was demonstrated by Prof. Slingerland in his field experimental work in the vineyards of Chautauqua County, N. Y., during the outbreak of 1901–2. Since it frequently happens that during seasons of heavy infestation the hibernating adults appear on the new foliage in injurious numbers and cause considerable alarm among the vineyardists, he attempted to combat them by means of a kerosene and water spray. He found, however, that the margin between the percentage of oil necessary to kill the adults and the percentage that would seriously injure the grape foliage was so small that more injury to the vines was likely to occur than would offset the benefit derived from the number of flying adults that were killed by the process.

Much greater success, however, was secured by him in spray applications made against the nymphs by the use of whale-oil soap at a strength of 1 pound of the soap to 10 gallons of water. With this spray liquid he was able, by one thorough application when the majority of the nymphs were present on the foliage, to reduce their numbers to such an extent that those remaining caused no serious injury to the vines for the remainder of the season.

In experiments with liquid sprays consisting of 1 pound of whale-oil soap to 15 gallons of water Mr. Quayle was able to destroy a very large percentage of the nymphs infesting grapevines in California. He was also able to obtain good results by the use of a spray consisting of 1 pound of resin to 15 gallons of water, using enough lye or potash completely to dissolve the resin. This required 1 pound of lye to about 8 pounds of resin.

The chief objections to the use of whale-oil soap are the very offensive odor connected with its application and the fact that since the vines have to be thoroughly drenched with the spray in order to strike the underside of all of the leaves, the clusters of grapes are also necessarily drenched. This soapy liquid has a tendency to form in a drop on the lower part of each berry, and after the moisture has evaporated a white stain remains which makes an undesirable discolora-

tion on the purple surface of the ripened grapes, rendering them unattractive for table use.

During the last few years commercial brands of tobacco extracts have come much into use as liquid spray substances for the control of soft-bodied sucking insects. Hence once more, after a period of over 80 years since it was first recommended, tobacco appears to be the most promising insecticide for the control of this pest.

During the seasons of 1910 and 1911 the grape leafhopper was present in very injurious numbers in many vineyards in the Lake Erie Valley. Vineyard experiments were undertaken by the Bureau of Entomology in the vicinity of North East, Pa., using the tobacco extracts as liquid sprays against the nymphs. The results of these experiments were very gratifying, since with one thorough application of the tobacco extract the numbers of these insects in the treated vineyards were so greatly reduced and the injury was so slight that the foliage retained its dark green color throughout the season, the cane growth was strong and well matured, the berries were large, the fruit sweet, and the size of the crop considerably increased; whereas, on the untreated portion of the vineyards the foliage turned brown and dropped prematurely, the cane growth was stunted, the berries were undersized and lacking in sugar content, and the tonnage per acre was much less than on the sprayed portions of the vineyards.

Detailed reports of these vineyard experiments against this pest are given in Part I of Bulletin No. 97 and Part I of Bulletin No. 116 of this bureau.

SPRAY MATERIAL.

The forms of tobacco extract used in these experiments in 1910 and 1911 were the blackleaf tobacco extract containing 2.70 per cent nicotine sulphate and the blackleaf tobacco extract containing 40 per cent of nicotine sulphate. The blackleaf tobacco extract containing 2.70 per cent of nicotine was effective in killing all of the nymphs which were thoroughly wetted by the spray, when applied at a dilution of 1 part of tobacco extract to 150 parts of water or Bordeaux mixture. The blackleaf tobacco extract containing 40 per cent nicotine sulphate was found to be effective at a dilution of 1 part of tobacco extract to 1,500 parts of water or Bordeaux mixture. Both of these forms of tobacco extract appear to be equally effective in destroying the nymphs at the dilutions mentioned. The one containing the smaller percentage of nicotine (2.70 per cent), however, necessarily contains more sticky inert matter. When this is applied as a spray to the vines late in the season, i. e., toward the middle of August, and when little rainfall occurs before the harvesting season, some of this sticky substance may adhere to the ripe grapes, giving the skins a slight flavor of tobacco.

It was noted that this condition obtained during the dry fall of 1910. The "blackleaf 40" tobacco extract does not appear to carry so much of this sticky substance, and owing to the greater dilution that is possible in its use the dilute spray liquid is almost clear; hence there is not the likelihood that it will leave the undesirable stain on the ripened fruit. It should be stated, however, that neither of these extracts is likely to leave the unpleasant stain or odor on the fruit if applied in the early part or middle of July, which is usually the period at which the maximum benefit is to be derived from them in the destruction of the nymphs.

SPRAYING APPARATUS.

Various types of spraying machinery are used by the vineyardists of the Lake Erie Valley. It was on account of the depredations of the grape rootworm, requiring a spray application to the upper surface of the foliage, that the use of spraying machinery in vineyards became general. The sprayer in general use for this work is of the tractor type (Pl. III, fig. 1), the power being generated either by a chain or an eccentric gearing connecting the wheel and the pump. Thus in order to maintain a uniform high pressure with this type of machine it is necessary to keep it in motion. Although most of these machines are supplied with a large air chamber so that the pressure is held quite steady and does not vary with every stroke of the plunger, yet as soon as the wheels of the machine stop turning the pressure drops quite rapidly.

Other types of sprayers in use for vineyard work are compressed-air power outfits, gasoline-engine power outfits, and steam power outfits. With all of these latter types the pressure is independent of the rate of movement of the machine through the vineyard rows.

In making spray applications against the nymphs of the grape leafhopper it is necessary to apply large quantities of spray liquid to the underside of the infested grape leaves. Where the foliage is quite dense the amount of spray required for thorough work may amount to from 200 to 300 gallons per acre, whereas in making applications to the upper surface of the foliage against the beetles of the grape rootworm thorough work can be done on quite dense foliage with about 100 to 125 gallons of liquid per acre, and this may be accomplished while the team is being driven slowly.

During the seasons of 1911 and 1912 all of the types of spray machinery previously mentioned were observed in use in spraying against the grape leafhopper, and in the hands of careful operators effective work was accomplished with all of them.

It should be stated that in all cases observed, with the exception of the steam-engine power outfit, all of the spray applications were made by the trailer method. That is, the operator directed the spray

to the underside of the grape leaves by holding a short rod, one end connected to the spray hose and the free end carrying a large nozzle of the cyclone type directed upward at right angles to the rod. (See Pl. III, fig. 1.) Effective results in killing the nymphs by this method appeared to depend more upon the person manipulating this rod than upon the type of sprayer used or the number of pounds of pressure applied, providing the pressure was not allowed to drop below 75 pounds. Of course with the higher pressure larger areas can be covered in a given time than with the low pressure. Yet the most effective work done in the control of this pest coming under observation of the writer was accomplished with a tractor machine, with a pressure fluctuating between 70 and 125 pounds, in the hands of a very thorough vineyardist. This feature is emphasized here because the small vineyardist, being under the impression that an expensive high-pressure spray outfit is necessary, is frequently deterred in attempting to control this pest, whereas the most important thing is care in the direction of the spray so that the greatest number of nymphs will be drenched, and this can be done with the same tractor machine that is used for applications against the grape rootworm. On the other hand, it is doubtless much more economical for the vineyardist with large areas to cover to have larger high-pressure outfits, since with them two or even more leads of hose may be used (Pl. III, fig. 2), making it possible to cover large areas in a very short time. This is highly desirable, since there are only about 8 to 12 days during which the maximum number of nymphs is present upon the foliage.

In order to lessen the time required to make the application and to reduce the cost, many attempts have been made to apply the spray to the underside of the grape foliage by means of a fixed nozzle arrangement instead of making the application by the trailer method described above. The chief difficulty arising in the use of a fixed-nozzle arrangement is that such a device applies no more liquid to a vine carrying a large amount of dense foliage than to one carrying a moderate amount of more widely spaced foliage; hence it frequently happens that much more spray than is necessary is applied to the vine carrying light foliage and not enough is applied to the one carrying dense foliage.

The types of fixed-nozzle arrangement are being tried out in the vineyards of the Lake Erie Valley. One of these was for a tractor or a gasoline-engine power sprayer, and was devised and used by Mr. F. Z. Hartzell.[1] The other arrangement was used for a steam-engine power sprayer. (Pl. II, fig. 2.) Both of these arrangements are reported to have given fairly satisfactory results in killing nymphs where the foliage was not very dense. In most cases, however, suc-

[1] Bul. 344, N. Y. (Geneva) Exp. Sta., Pls. I–IV.

FIG. 1.—ROD AND SINGLE CYCLONE NOZZLE USED TO APPLY SPRAY TO UNDERSIDE OF GRAPE FOLIAGE. POWER SUPPLIED BY TRACTOR SPRAYER. VINEYARD OF MR. H. H. HARPER, NORTH EAST, PA. (ORIGINAL.)

FIG. 2.—GASOLINE-ENGINE SPRAYER SUPPLYING POWER FOR TWO "TRAILER" LEADS OF HOSE IN SPRAYING AGAINST THE GRAPE LEAFHOPPER. VINEYARD OF MR. J. E. BEATTY, NORTH EAST, PA. (AUTHOR'S ILLUSTRATION.)

cess with any type of spray apparatus in present use in work against this pest appears to depend more on the care and ingenuity of the individual operator than upon the great superiority of any given type of machine over another.

RECOMMENDATIONS.

Efforts to control the depredations of the grape leafhopper by the destruction of the winged adults, by burning over or cleaning up their hibernating places adjacent to vineyards, by trapping them on sticky shields, or by endeavoring to treat them with contact sprays when they appear on the new growth of the grapevines in spring before oviposition takes place, have proven far from satisfactory. Although these methods may furnish a certain measure of relief over very limited areas, they are of very slight practical value as control measures when serious infestations occur in large vineyards.

Observations indicate that except in seasons of extremely heavy infestation, or over limited areas, the injury wrought by the overwintering adults in spring to the new growth is not likely to reduce greatly the entire seasonal growth of the infested grapevine provided a large percentage of their offspring in the form of nymphs can be destroyed before they reach the adult stage. In other words, it is the steady drain made on the infested grapevines from the time the overwintering adults attack them in spring, combined with the unchecked attack of the nymphs and adults of the new brood until late September, that results in serious injury by curtailing the size of the crop and the growth of the vine.

That the nymphs can be controlled by the spray method has been thoroughly demonstrated. Successful control of the nymphs by this method depends on thoroughly wetting all parts of the underside of the infested leaves with the spray liquid.

Tobacco extracts have given excellent results, used according to the following formulas:

I. Tobacco extract containing 2.70 per cent nicotine sulphate, diluted at the ratio of 1 part to 150 parts of water.

II. Tobacco extract containing 40 per cent nicotine sulphate, diluted at the ratio of 1 part to 1,500 parts of water.

The killing quality of the tobacco extract is apparently just as effective when added at the same dilution to the Bordeaux mixture and arsenate of lead spray liquids, which are used to control fungous diseases and chewing insect enemies of the grapevine, as when used with clear water. No injury results from combining these spray mixtures, namely, tobacco extract, Bordeaux mixture, and arsenate of lead. However, the tobacco extract should not be mixed with spray mixtures containing arsenicals in the form of Paris green or arsenite of lime, for serious injury to the foliage is likely to occur as a result of the combination.

The most effective time to make the tobacco spray application against the nymphs is just before those that hatched earliest in the season have reached the fourth molt. This can be determined by the length of the wing pads (Pl. I) which, in the fourth stage, extend about one-third the length of the abdomen. At this time a larger number of nymphs are likely to be present on the vines than at any other time during the season. In the vineyards of the Lake Erie Valley this condition occurs toward the end of the first week in July, and the most effective work with the tobacco-spray liquid may be done during the two weeks following this date. After this period, or toward the end of July, a large percentage of the nymphs of the first brood will have transformed to winged adults, and these latter can not be successfully treated with the diluted tobacco spray.

In vineyards where black-rot, mildew, the grape rootworm, and the grape-berry moth occur, it is suggested that arsenate of lead and Bordeaux mixture be used with the tobacco extract to take the place of the second spray application in the schedule of treatment recommended against these diseases and insect pests.

When it is deemed expedient to use sticky shields to capture the winged adults before oviposition takes place, the best sticky substance for this purpose, according to Slingerland, is a mixture of melted resin, 1 quart, in 1 pint of castor oil, smeared liberally over the face of the shield.

CONCLUSIONS.

Typhlocyba comes, the species of grape leafhopper discussed in this paper, is at the present time a very destructive enemy of the grapevine throughout the vineyards of the Lake Erie Valley. For several seasons it has caused great losses to the vineyardists of this region by reducing the yield and quality of the grape crop and by curtailing the growth and lowering the vigor of the vines. The vineyardist who desires to maintain his vines in full vigor and produce high-quality fruit can not afford to allow this pest to develop in destructive numbers in his vineyards, for if not controlled sooner or later it is almost sure to occasion serious loss. Field experiments prove conclusively that this pest can be controlled by spraying against the nymphs with a tobacco-extract solution.

The life-history studies recorded in the preceding pages show that there is only one full brood of nymphs a year in the region of the Great Lakes.

The spraying experiments recorded in Part I of Bulletin 97 and Part I of Bulletin 116 of the Bureau of Entomology indicate that a single thorough spray application, made when the greater percentage of the nymphs of this brood is present on the underside of the grape leaves, will so reduce their numbers that injury to the crop and the

vines for the remainder of the season by those that escape the spray action will be very slight.

In the vineyards of Ohio, west of Cleveland, and in the vineyards of Michigan another species of grape leafhopper, *Typhlocyba tricincta* (figs. 6 and 7, pp. 10, 11), is the predominant and destructive species. The life history and habits of this species, however, are so nearly identical with those of *Typhlocyba comes* that the remedial treatment recommended for the latter can also be used with success against the former, namely, the application of the tobacco-extract spray to the nymphs at the time they appear in maximum numbers upon the underside of the grape leaves, which for these States is during the last few days in June or very early in July.

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THE MANAGEMENT OF SHEEP ON THE FARM.

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Of the Animal Husbandry Division.

INTRODUCTION.

Sheep husbandry should receive more attention from the farmers of this country than it does at the present time. Unquestionably sheep raising could profitably be fitted into the general management of thousands of farms where there is none at the present time. On many other farms the size of the flock could be increased and more attention given to this branch of farming with resulting profit to the owner.

The various phases of sheep husbandry afford numerous channels through which the skill of the producer can display itself. The breeding of purebred stock offers special inducements to many, while a larger number are content with the production of mutton and wool for market purposes. In the breeding of purebred stock the beginner has a number of valuable breeds from which he can make a selection. It is not so much the breed selected that will lead to success as it is the care and management. It must be noted, however, that certain breeds have a wider range of adaptability and are more popular. The number of purebred flocks is increasing every year and the demand for good breeding stock is more than keeping pace with the increase.

With a commercial flock there are several phases that are worthy of consideration. Early spring lambs is one of the most important, while late spring or early fall lambs should receive due consideration. The production of winter or so-called "hothouse" lambs is well worth undertaking by those who are favorably situated. This early lamb is a high-priced product and should prove profitable under favorable conditions.

Many farmers have disposed of their flocks and many others have refrained from entering the business because of some of the difficulties that are peculiar to this industry. Among the most important of these are our dogs, parasites, and diseases. A certain amount of trouble is inevitable where these abound, but ordinarily this should

not be sufficient to discourage the flock master. Good management and proper care will control, if not eliminate, these difficulties. The flock that must rustle for itself is the one that suffers most from these sources. Sheep are good scavengers, but should not be made to subsist upon weeds alone, with little or no attention on the part of the farmer. The sooner the owner realizes that his sheep can not return satisfactory profits under such conditions, the better it will be for him. Any extra care and feed given to the flock generally yields the greatest returns.

Sheep have ever been in the vanguard of civilization. This country has been no exception in this respect. The magnetism of cheap lands has constantly drawn the industry westward, creating a quite general impression that sheep are unprofitable upon high-priced land. This may have been true in the past, but the industry is undergoing an evolution. The range is almost completely occupied and is constantly decreasing in extent. The cost of running sheep in the range country has gradually increased, and to-day many western people are returning to the east for the purpose of raising sheep. The period of exploitation is passing and a new era of constructive live-stock farming is at hand, which means that a more intensive system of sheep farming upon high-priced land must follow. This is already in evidence in certain localities and, with better care than is now generally given the sheep, should prove more extensive. In England the question is not whether you can afford to keep sheep on high-priced land, but whether you can afford to keep high-priced land without sheep.

THE VALUE OF SHEEP ON THE FARM.

INCREASE IN SOIL FERTILITY.

Sheep will increase the fertility of the soil if they are handled properly. To do this they should not be permitted to crop off the grass too closely, which they will do if the pasture is overstocked or if they are kept too long in one field. Sheep manure, with one exception, is the most valuable of all farm manures. It is thinly and evenly scattered over the ground and does not produce a rank growth in spots of the pasture as do other manures. The manure is also worked into the soil by the sharp hoofs of the sheep, so that it is not washed away but becomes available as plant food. This quality has well earned for sheep the title of "Golden hoof." In England land which during Queen Elizabeth's reign produced only 6 bushels of wheat per acre has been made to yield 30 bushels at the present time by the use of sheep. Better cultural methods may be the cause of a portion of this increase, but without doubt the sheep are responsible for the greater part of it.

DESTRUCTION OF WEEDS.

Another equally important way that sheep increase the productivity of the land is in their destruction of weeds. By eating the weeds they make more room for the cultivated crops and increase the supply of plant food and water available for them by preventing the weeds from using it. No other class of live stock, with the exception of goats, will eat as many weeds as sheep. By converting these waste products into wool and mutton they are a source of profit to the owner.

It has been estimated that sheep will eat 90 per cent of all troublesome weeds. They are, in fact, commonly used in cleaning up weeds from fields, fence rows, road sides, stubble fields, and corn fields. The common belief among farmers is that weeds eaten by sheep are so broken up in the digestive processes that the seeds will not germinate after passing through the body as in the case of other live stock. However, weeds are rarely permitted to go to seed if enough sheep are turned in the field while the weeds are young and tender.

In some investigations carried on by the Canadian Government among a considerable number of sheepmen to determine the kinds of weeds eaten by sheep, it was generally agreed that sheep would consume all but a very few extremely unpalatable ones, such as mullein, Scotch thistle, etc. Upon inquiry as to the specific kinds eaten, one farmer replied that he could not give any definite information on the subject as the sheep kept his farm so free from weeds that he could not see what kinds they actually ate.

Where sheep have been kept, but where for some reason they have been disposed of, a striking difference has usually occurred in the appearance of the farm. Weeds have sprung up and grown where they had formerly been kept in check. There is no better solution to the weed problem than a flock of sheep.

ESTABLISHING A FLOCK.

In establishing a flock it is better for the farmer to start on a small scale, unless he has previously had experience. When one is dealing with small numbers, a mistake in management or an error in judgment is not of so great importance as where larger numbers are involved. Starting with a small flock requires less capital also. If it is desired to augment the size of the flock, this can be done by the natural increase, the best ewe lambs being selected each year for the purpose. This should prove more economical than buying all the breeding stock outright. Where the stock is produced on the farm, only the cost of production can rightly be charged against it, but where it is purchased the cost of production plus a profit and very often the price of the reputation of the breeder must be paid. By producing

the breeding stock himself, the farmer should secure a more uniform lot and one better adapted to his own particular conditions. Another advantage of small numbers, especially where capital is limited, is that better animals can be purchased.

A GRADE FLOCK.

A grade flock is desirable under certain circumstances. Where market stock is the sole aim it will doubtless pay better to use grade ewes. It is the improved blood that makes a grade valuable. This being the case, the highest possible grade ewes should be purchased. By using a purebred ram on these ewes—and this is the only kind of ram that ever should be used—a flock can be developed to such a degree of purity that for all market purposes it is equal to the purebred flock.

Again, the financial risk is less with a grade flock, as there is less money invested. A grade flock can at any time be disposed of for its market value. This is not the case with pedigree stock, which, if it must be done immediately, without previous notice, can be sold only at a portion of its actual value.

CONVERTING A GRADE FLOCK INTO A PUREBRED ONE.

A grade flock can gradually be converted into a purebred one at small cost by buying a few purebred ewes and by replacing the grade ewes with the offspring of the purebreds. This is, of course, assuming that a purebred ram heads the flock. This scheme also has the advantage of offering experience to the breeder during a time when his flock is not so valuable.

A PUREBRED FLOCK.

Purebred stock has a number of advantages over grades. These may be divided into natural and artificial. The natural or inherent advantages of purebred stock arise from the fact that there has been a concentrated effort in the development of the better breeds to establish, intensify, and perpetuate their superior qualities by using only the best animals for breeding purposes. There have been some exceptions to this, some inferior animals have entered, but the formation of a breed has in general been based upon superiority in some form. Nevertheless, owing to the reappearance of inferior individuals, not all purebred sheep are suitable to retain in the flock.

A breeder of purebred sheep can develop a reputation that never could be acquired with grades. The sales of pedigree breeding stock extend over a much wider range of territory than those of market stock. The show ring also spreads abroad the fame of the breeder of purebred stock. Larger prices are obtained for purebred ewes and rams when sold for breeding purposes, although it costs little more to

produce them after the flock is once established. There is also more stability in their values than in those of market stock.

Certain artificial advantages have been set up by the establishment of the breeds, because of set regulations that must be met as a condition of registration under these breeds. For instance, no matter how nearly a grade may approach a purebred in identity of blood lines, it never becomes eligible to registry in the associations of the well-established breeds.

CROSSBRED SHEEP.

At times the market, or the natural conditions of a new country, may demand a type of sheep that can best be produced by crossing two breeds. If a demand of this nature is other than temporary a new breed is developed, or the existing breeds are so changed that they fulfill the demand. The Corriedale sheep of Australia and New Zealand are a breed resulting from crossing to meet market demands. As a rule, crossing is not very satisfactory. The reasons for this are that the breeding stock must be maintained separate or brought in from outside the flock and that the lambs are not very uniform, especially after the first generation. Some English investigations indicate that crossbred sheep are less fertile, but it is doubtful whether there is enough difference in this respect to be of any importance.

Cross breeding among the medium and long wool breeds has been rarely practiced in America. Crossing the fine wools with the medium and long wools has been done to a considerable extent in the range country, but to a rather limited extent upon the farm. The general practice has been to use mutton rams upon merino ewes. The object of this crossing has been to improve the mutton qualities, or, in other words, to meet a market demand. In England cross-breeding is a very common practice; purebred ewes, after producing several crops of lambs, being mated to rams of other breeds.

GENERAL TYPE OF SHEEP FOR THE FARM.

The farmer's sheep should be a wool and mutton sheep, with emphasis upon mutton. This "dual purpose" sheep, if the name be permissible, is a proved success, and it is already represented in some of the breeds. The best type is the most profitable combination of wool and mutton. The investigations of the Tariff Board [1] indicate that sheep farming for wool alone is unprofitable. In investigating 543 flocks of the fine-wool section of Ohio they found that when there was a net credit to wool the percentage of receipts from wool was 38 and from other sources 62. If the raising of sheep for wool alone does not pay in this region, it probably would not in any other part of the farming section.

[1] Report of the Tariff Board, vol. 2, pt. 2.

IMPORTANCE OF PROPER SELECTION.

Selecting the breeding stock is the most important operation in establishing the flock. It would be a much simpler problem if the visible qualities, such as form, were the only ones concerned, but such is not the case. Functional characteristics, such as fecundity and good milking qualities, are equally important. Too much attention can not be given to this phase of selection. Upon success or failure of proper selection depends the advance or retardation of the flock. The old adage, "Well begun is half done," was never more appropriate than here.

IMPORTANCE OF SELECTING HEALTHY BREEDING STOCK.

It is necessary to pay special attention to the health of the breeding animals. Sheep are affected with so many diseases and parasites that extreme care must be exercised to select individuals free from these troubles. The sheep of the corn belt have been especially troubled with parasites. It is because of the comparative freedom of the range from these pests, and the consequent vigor and robustness of western sheep, that this class of sheep are particularly desirable for breeding purposes.

SELECTING PUREBRED STOCK.

With purebreds there are certain breed characteristics that must be given their due consideration. These may or may not be of value in themselves, but at any rate they are important in that they indicate purity of blood, which blood contains unquestionably superior qualities.

The different breeds are all undergoing more or less of a change. Part of this is actual improvement and part of it is fashion. It is desirable that the breeder of purebred sheep keep up to date in his selection, avoiding "off-type" sheep. He should do this whenever the newly desired qualities do not interfere with the usefulness or value of the sheep; but where constitution, utility, or some other such quality must be sacrificed to fashion, it should be avoided, and more progress will be made in the end. The most improved and at the same time the most up-to-date type should be selected.

With purebred stock it is desirable, if possible, to select all the ewes from the flock of one reliable breeder. More uniformity, both in the ewes themselves and in the lambs, can thus be secured. The purchaser should make it a point to see the stock before buying. If this is impossible, the stock should be shipped subject to approval. Many breeders' show flocks are comprised of purchased or imported sheep of high quality, while their breeding flocks are of a very mediocre character.

SELECTING THE RAMS.

The ram has as much influence upon the flock as the entire ewe flock bred to him, which fact gives rise to the old saying, "The ram is half the flock." The selection of the ram is thus seen to be a matter of prime importance. Improvement in breeding can be brought about in a flock at less expense by the use of a good ram than in any other way. A good ram is a valuable investment, and the few extra dollars in cost over the price of a mediocre one multiply themselves in returns on the lamb crop. The wise selection of a single ram has in many cases made a flock famous.

The qualities desired are that he be a well-balanced individual, bold, and of masculine character, and with abundant vigor and style of carriage. He should be a representative of the most improved breed character and should possess a strong constitution, as indicated by a short, broad head; large, dilated nostrils; a short, thick neck; a broad, deep chest; and a large heart girth.

Abundant digestive capacity is also essential, and it is shown in a large muzzle and a broad, deep middle. A somewhat paunchy ram is often a good breeder, and a certain amount of this is permissible, but when developed to an extreme it is unsightly and is discriminated against. As much quality as is possible without sacrificing strong bone, size, and ruggedness is desirable. It is indicated by density of bone, fineness of fiber and hair, and a general absence of coarseness. The degree of quality present in some breeds is greater than in others, but an excess of refinement is out of place in a ram of any breed.

The head should be masculine, with a clear prominent eye. The neck should be full, swelling gradually to meet the shoulders. A "ewe neck" is very objectionable. The shoulders should be broad but not prominent; level on top, with no tendency toward openness. The breast should be broad and full, the forearm well developed, the forelegs straight and wide apart, and the pasterns strong.

The ram should not be deficient back of the shoulders, but should carry his width in a broad, straight back, well-sprung barrel, and full flank. The loin should be broad and level, the rump long and broad, with no tendency toward droopiness or a pointed rump. The twist should be deep and full, the width of the quarters carrying down in well-developed legs of mutton. The rear flank should be full and well let down, the hind legs straight, without weakness in the pasterns.

The fleece, as nearly as possible, should be uniform over the different parts of the body and should be characteristic of the breed. The skin should be of medium thickness and of a good healthy color for the breed.

It is desirable that he be deep muscled, but to a certain extent this depends upon the care, feed, amount of service, etc. A ram that is

inherently deeply fleshed should be selected, as he is more easily kept, and his lambs will ordinarily have like tendencies.

Endeavor to secure a ram that is prepotent. It is impossible, of course, to determine this in an untried ram, but a superior pedigree is a good indication of it. The object should be to combine individuality with good breeding.

Overfitted rams are never desirable for breeding purposes. They require a long time for reduction to breeding conditions, which should be brought about by abundant exercise and a gradual decrease of rations. By the time they are in breeding condition the mating season is far advanced and a late crop of lambs will result. Very often these overfitted rams are infertile. The breeder should see that the ram is entire (having two testicles) and free from goiter. Never use a ram for breeding that is affected with this disease.

AGE OF BREEDING RAMS.

Ordinarily a yearling or a 2-year-old ram is most satisfactory for breeding purposes. Ram lambs are used to a limited extent when older rams are unavailable. The extent of their use varies with the different breeds and with their age at the breeding season. It is not usually desirable to breed ram lambs to more than 10 or 15 ewes, and 25 should be considered a maximum number. If bred excessively they become stunted and frequently prove nonbreeders afterwards.

Ram lambs are frequently purchased because they are cheaper than older rams. A good ram lamb not infrequently proves a poor yearling, and even with a yearling there may be considerable change before maturity. Wisconsin [1] experiments indicate that the lambs from a yearling ram averaged less in weight at birth than those from older ones. No results were reported on the weights of lambs from ram lambs.

Sometimes an older ram whose breeding qualities are known can be secured very reasonably, where the breeder disposes of him to avoid in-breeding. A ram of this kind often proves a bargain. In a small flock a ram can be used for two seasons, which is as long as a ram can be kept at the head of the flock without breeding him to his own lambs, and this is generally not advisable. In a large flock a ram can be kept longer without in-breeding.

SELECTING THE EWES.

With the ewes as much as possible of the ideal form is desirable, but it is impossible to secure as complete an expression of this as with the rams. The heavier demands made upon the ewes in reproduction prevent it. For this reason, too, much attention should not be given to mutton form in selecting the ewes, to the exclusion of

[1] Agricultural Experiment Station of the University of Wisconsin, Bulletin 95, Madison, 1902.

PUREBRED FLOCK OF SOUTHDOWN SHEEP AT THE MORGAN HORSE FARM, MIDDLEBURY, VT.

An excellent purebred flock, showing a marked degree of uniformity.

FIG. 1.—DOG-PROOF INCLOSURE IN WHICH THE FLOCK IS KEPT AT NIGHT.

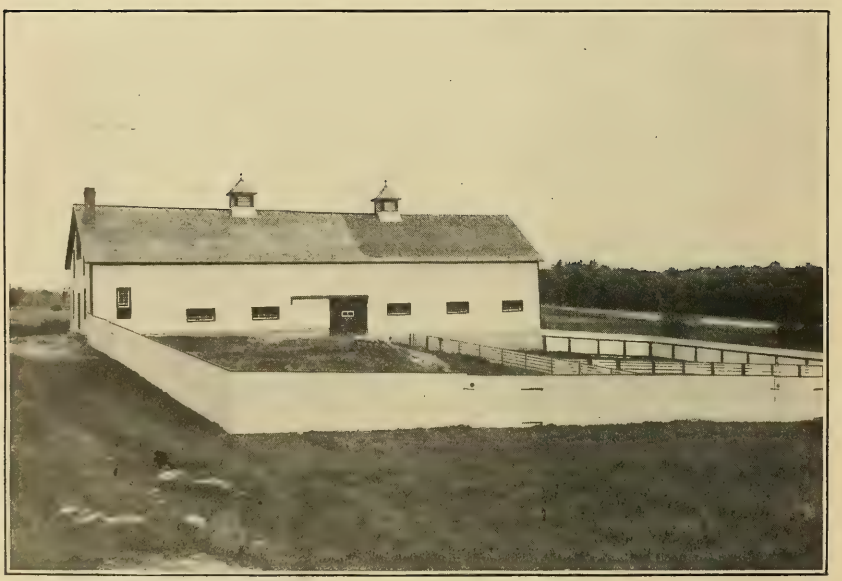

FIG. 2.—SHEEP BARN AT MORGAN HORSE FARM, MIDDLEBURY, VT.

other qualities. Large, roomy ewes possessing some degree of "dairy type" raise the best lambs. Very often the barren ewe, or the one that has lost her lamb, apparently possesses superior mutton form, but this is not due to inheritance, but to the fact that the animal has not suffered the drain of producing and rearing young. Short, plump, "tucked up" ewes are not desirable for breeding purposes.

Femininity is as desirable in the ewe as is masculinity in the ram. While to a certain extent this character accompanies refinement, it should not be mistaken for weakness or an excess of quality. Ewes that are good mothers should be selected as far as possible. This is to a certain degree an inherited quality, though older ewes usually prove better mothers than younger ones. Ewes that disown their lambs or do not have enough milk for them are the source of a great deal of annoyance. It is said that these two conditions are correlated.

Where it is possible, the ewe's former record of production or that of her ancestors should be considered. English investigations covering 327 flocks showed that a ewe which was herself one of twins gave birth to twins more frequently than one that was a single lamb. The Wisconsin station [1] found that twin lambs gain as fast as singles, and that the ewes need lose no more flesh in nursing twins than single lambs. These observations indicate that a ewe that produces twins has more capacity than one raising only a single lamb and that she should prove more valuable in the flock. There are a number of instances where a ewe has produced as many as four lambs that have all lived and grown to maturity, though all were not suckled by the one ewe. There are ewes in every flock that are capable of raising twin lambs, and the number of these can be increased if an effort is made to do it.

This makes plain the importance of keeping accurate records of the flock. Probably not one farmer in a thousand keeps records, so there may be none kept of the flock from which the ewes were originally selected. But there should be a breeding record started as soon as a flock is established, especially if it is a purebred flock.

AGE OF BREEDING EWES.

It is impracticable to give any best age for breeding ewes. Desirable qualities are not all present to the greatest degree at any one time. For instance, the Wisconsin station [2] found that ewes 6 years of age produce a higher percentage of lambs than younger ones. But ewes this old usually have broken mouths and are not generally desirable on that account. Some general rules are worth considering

[1] Agricultural Experiment Station of the University of Wisconsin, Sixteenth Annual Report (1899), Madison, 1900.

[2] Agricultural Experiment Station of the University of Wisconsin, Bulletin 95, Madison, 1902.

on this subject. Ewe lambs are not satisfactory for breeding. With the ram lamb the amount of service can be regulated, but with the ewe lamb that is bred the entire burden of maternity must be borne, as it can not be controlled. An English experiment [1] showed that ewe lambs bred at seven months, when producing and rearing a lamb were stunted to the extent of 17 pounds as compared to those bred at one year and seven months. During the second year of the experiment the difference was lessened, but did not disappear. Ewes should not be bred before 18 months old, and this is the common practice in this country.

In founding a flock it is better to select ewes that have produced lambs. They have less trouble in lambing and something can be told of their breeding qualities.

Overfitted ewes are as undesirable as are rams in the same condition. They rarely produce after this condition has appeared. The presence of fat in the ovaries, or rather the conditions under which it is put on, is destructive to the reproductive organs. They are among the first parts of the body to suffer from high condition.

SIZE OF THE FLOCK.

The number of sheep that can be profitably kept will depend somewhat upon each farmer's conditions. The size of the farm and the number of acres that can be devoted to sheep, the natural fertility of the land, and the system of farming must all be considered. Whether sheep are a specialty or whether a small flock is kept for cleaning up the farm and increasing the fertility are other considerations. During the past, the prices of wool and mutton have had a powerful influence upon the size of farm flocks. There has always been a tendency for most farmers to dispose of their flocks when prices become low and to enter into the business again when the prices become high. Where purebred sheep are kept the size of the flocks are, as a general rule, much smaller.

The work of caring for the flock should be considered in determining the size. Certain chores must be done, and many of these would take little more time with 50 than with 15 or 25 head. Much of the equipment needed for a smaller flock will serve for a larger one. A ram will be necessary for a dozen ewes, while as a matter of fact a mature one could be bred to 50 ewes fully as well.

As a general rule, under mixed farming conditions, one sheep to 3 to 5 acres is considered advisable. The question should not merely be "How many sheep can you keep?" but "How many can you keep healthy?" A small healthy flock is much preferable to a larger one that is diseased.

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[1] Journal of the Southeast Agricultural College, Wye, 1909, No. 18.

CARE OF THE FLOCK.

SPECIAL PRECAUTIONS.

Probably sheep are subject to more ills than any other class of domestic animals. At any rate, they seem to be more helpless in repelling the attacks made upon them. This need not discourage the prospective shepherd, since good care and management will obviate most of these troubles. Upon this care and management depends the "luck" of the shepherd. Flocks are known to exist upon weeds and waste roughages with little or no attention, but the returns are proportionately meager.

DOGS.

A well-trained sheep dog is one of the greatest friends of the industry, while the cur dog is one of its worst enemies. The Scotch collie is the sheep dog of America, and a well-trained one can not be appreciated unless seen at work. Their tireless watching, even at night, makes them invaluable to the sheep herder. By their barking they warn him of any prowler that may be lurking about the flock. However, a poorly trained dog, as is found on many farms, is more of a nuisance than a benefit in handling the flock. It is unfortunate that the collie has not found a larger place in flock management on the farm. On the average farm it is the other side of the dog problem that concerns the shepherd. The cur dog has driven many a farmer out of the sheep business and has prevented many more from entering it. The loss to the sheep industry from this source can hardly be estimated. A leading eastern paper on May 28, 1910, printed the following:

> Seventy-five sheep have been killed and 152 have been bitten by dogs that came into the neighborhood last week. Of the 35 flocks of sheep of this town, only 1 escaped the ravages of the dogs. Damages are estimated at $500.

There are thousands of such cases on record. However, the loss in killed and injured is not all the damage. Once the flock has been ravaged the sheep become restless and excitable, and weeks often elapse before they are again making normal gains. Other flocks never fully recover from such attacks and consequently must be disposed of. The reimbursement the farmer receives rarely covers the value of the sheep killed, disregarding the other damage altogether.

There is no complete solution for the dog problem, but there are a number of remedial measures. Among them are more sheep, better dog laws, dog-proof wire fences, sheep bells, and the elimination of the cur dog.

In many sections of the country the raising of more sheep would aid along this line, and this is especially true where only one or a few farmers in a neighborhood are keeping sheep. If every farmer, or a

majority of them, were interested in the industry the dog would stand a poorer show of doing any damage.

A number of sheep bells should be used in the flock. The sheep bell serves as a warning when the flock is being disturbed. The number of bells will depend upon the size of the flock, but with the ordinary farm flock from two to six bells are sufficient.

The elimination of the cur dog needs no further comment. Each farmer should be governed by his own conditions. Farmers in many localities have made use of the telephone in informing their neighbors of the appearance of stray dogs and much damage has been averted as a result.

DOG LAWS.

A more rigidly enforced dog law would rid the country of many of the worthless mongrels. The present taxes on dogs are too often evaded. The following extract from the dog laws of Great Britain is taken from the Canadian Department of Agriculture's report upon the sheep industry and is worthy of consideration in enacting more rigid dog laws.

Dog laws in Great Britain are very simple and very effective. In England and Scotland the license fee is 7 shillings and 6 pence ($1.80) a year. Everyone must pay this license, rich and poor alike, because the law is strictly enforced. Sheep dogs, however, are exempt under certain conditions. If a farmer can prove that he has sufficient sheep and cattle to make it necessary for him to keep a trained dog, he applies for an exemption form and fills it out. When this has been handed to the officer in charge of the nearest inland revenue office, he gets an exemption certificate for that year. If the farmer keeps a sporting dog or a pet dog, no exemption is granted.

In Ireland the license fee is 5 shillings ($1.20) a year, and no exemption whatever. Blind persons in any part of the United Kingdom can also obtain an exemption certificate, providing they can satisfy the authorities that they possess a dog trained to lead them on the highway. The license is not collected for pups under 6 months old, and special arrangements are provided for registered packs of hounds. Licenses are issued at every post office, as at the inland revenue offices. Every dog must wear a collar, to which is attached a small brass disk bearing the owner's name and address and the license number.

Dogs found straying about towns and villages without their owner or other guardian may be seized by the police and, after being detained for three days, unclaimed, are destroyed. When they are claimed the owner is required to pay all expenses incurred during that time. In this connection dog homes are maintained in all towns and villages for the purpose. Although the dog laws are rigorously enforced, they are so well observed that legal actions are very rare.

Sheep worrying by dogs is scarcely known in agricultural districts, and most farmers we interviewed had never had a case of this nature. In some localities adjoining towns and villages they are not so free from this trouble. Such cases are mostly found in congested mining districts, where useless idle dogs are often found. Sporting dogs are also a source of danger, but they are usually well guarded.

Whenever a case of sheep worrying does occur, and the dog is caught in the act, he may be shot at once, but in cases where valuable dogs are caught in mischief, such as fox hounds, the farmer generally traces them to their owner, who gladly meets all the farmer's claims rather than suffer the loss of the dog. When, in other instances,

cases are taken to court, if ownership of the dog is proved, and also that the said dog committed the damage, the dog is ordered to be destroyed and the owner obliged to settle damages in full. Claims for losses may be settled through the county council, but the law is so well observed and loss so rare that private settlements are the general rule.

DOG-PROOF FENCES.

Sheep are more frequently killed at night than during the daytime, and this simplifies the working out of satisfactory measures for prevention. Even with a good dog law a breeder would not care to run any risk of having his flock ruined, and he may, by the use of a dog-proof woven-wire fence, add further protection. In a great many cases farmers could not afford to fence their entire land devoted to sheep grazing, but it is a very simple matter to fence off a small inclosure, as shown in Plate II, figure 1, in a convenient place and keep the flock in this at night. This system has been adopted by many farmers and is to be highly recommended. Wire fence is very durable, and at the present time can be purchased very reasonably, and should be used on more farms devoted to sheep raising. The Department of Agriculture uses a 25-bar, 58-inch, rabbit and stock proof woven-wire fence around its sheep pastures at the Morgan Horse Farm in Vermont

PREVENTION OF DISEASE AND PARASITES.

The prevention of disease is always more effective and economical than the cure. Every precaution should be taken to keep up the health of the flock, thus warding off as far as possible the attacks of disease. Many of these attacks are the indirect result of failure to give the flock proper attention. An abnormal condition of the parts suffering from neglect affords an easy entrance for disease. Foot rot, which may result from failure to trim the feet and from allowing the flock to run on poorly drained pasture, is a good example.

Parasites are also very troublesome to sheep and are probably the cause of as many failures as any other one thing. Stomach worms are the most troublesome of these at the present time. Rotation of pastures and avoiding land that has been grazed over by infected flocks tends to hold these parasites in check. Precautions should be taken against introducing infected stock into the flock. Many flocks that have been entirely free from disease and parasites have suffered severe outbreaks as a result of failure to observe these precautions.

HANDLING SHEEP.

It is quite as important that sheep be handled properly as that they be properly fed. Ignorance is the cause of a great deal of mishandling, and carelessness is to be blamed for the rest of it. The correct way of handling is the easiest after it is once learned.

CATCHING.

Formerly the shepherd's crook was used largely for catching sheep, as it is still used in England and Scotland and in the West. The crook is used to catch the sheep by the hind leg. Sheep should be confined to close quarters when they are to be caught or handled. They can best be caught around the neck, by the flank, or by a hind leg immediately above the gambrel joint. After being caught the sheep can be easily led by placing one hand beneath the lower jaw and the other to the rear of the buttock. A little pressure upon the dock will usually persuade the most stubborn sheep to lead readily. Sheep should never be caught or led by the wool. Doing this causes a bruise that requires weeks in healing, and there is no necessity for it.

SETTING A SHEEP UPON ITS RUMP.

There are a number of ways of setting a sheep on its rump. Quite commonly they are lifted by main strength and placed in this position. This is difficult for the operator where the sheep is a large one, and it necessitates more or less rough handling of the sheep. A far simpler and easier method is as follows: Taking a stand upon the left side of the sheep, the left arm is placed around the neck. With the right hand grasp the right hind leg just above the fetlock. Pull the hind leg in under the sheep and lift backwards with the left arm. In this way the sheep is set back upon its rump in the easiest possible way. When through with the sheep shove it forward upon its front feet and it can readily rise without needless struggling.

LOADING.

Sheep can be lifted into a wagon handily in the following way: One person stands on each side of the sheep. The right hand of one grasps the left hand of the other between the fore legs of the sheep. The other hands are grasped in a similar manner beneath the hind flanks. In this way the sheep can be lifted quickly and with little effort. A loading chute made of inclined planks with cleats across them to prevent the sheep from slipping is a convenience in loading large numbers. Sheep should never have their legs tied in transportation. A special sheep rack or wagon should be used when many are to be hauled, while if only two or three are being transported they can be tied in the wagon or crated. (See Plate III, fig. 1, and text fig. 1). When shipped a long distance in a crate special arrangements must be made for feeding. If a gunny sack is tacked loosely over the front end of the crate sufficient hay can usually be placed between the sack and the crate. A receptacle for water and grain should also be fastened in the front end of the crate.

HURDLES.

Hurdles are a great aid in handling sheep under certain circumstances. They are convenient in pasturing on rape and similar crops where the sheep are to be confined to a portion of the field. This is desirable in that it prevents the sheep picking out the choicest pasture first and leaving the poorest for the last when, as a matter of fact under fattening conditions, the best should be available. Fencing off part of the field in this way also makes more frequent the rotation of pasture. Woven-wire fencing is also used for making temporary inclosures. Drawings and dimensions of sheep hurdles are shown in figures 2 and 3.

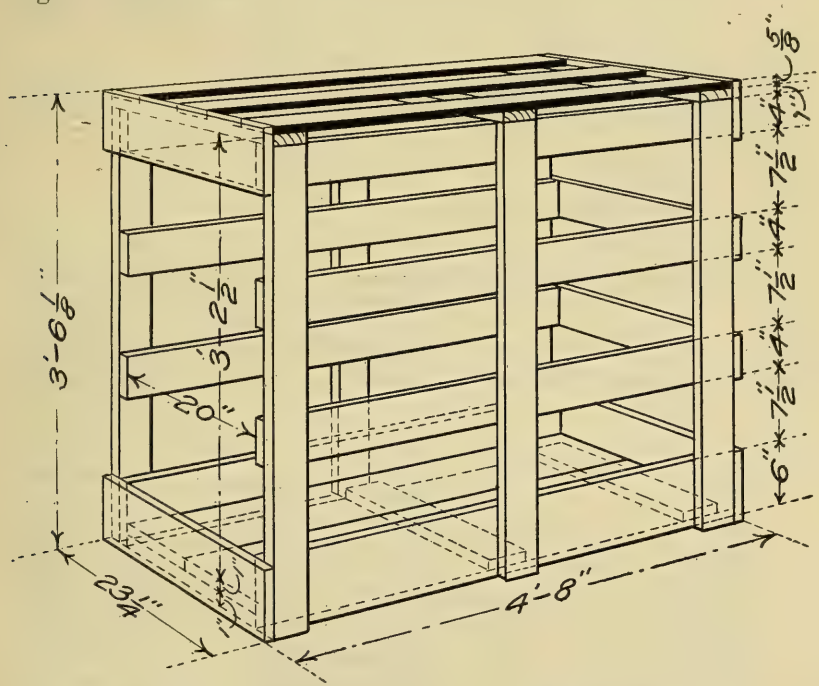

FIG. 1.—Showing dimensions of a crate similar to the one shown in Plate III, figure 1.

Netting has largely taken the place of hurdles in England. Both cord and wire netting are used. The former has proved the more popular. The cord is water-proofed by a mixture of oil and tar. The netting is fastened to temporary stakes either by the use of ropes or staples. Sheep farming in this country has not been intensive enough to warrant a very extensive use of these appliances, but they may be more in evidence in the future. Hurdles are also convenient in making temporary pens. Lighter hurdles that can be handled readily have a place upon every sheep farm. They are well worth their cost.

PENS AND LOTS.

Sorting pens and lots are very useful, especially if the flock is of any considerable size. It is often desirable to separate the different

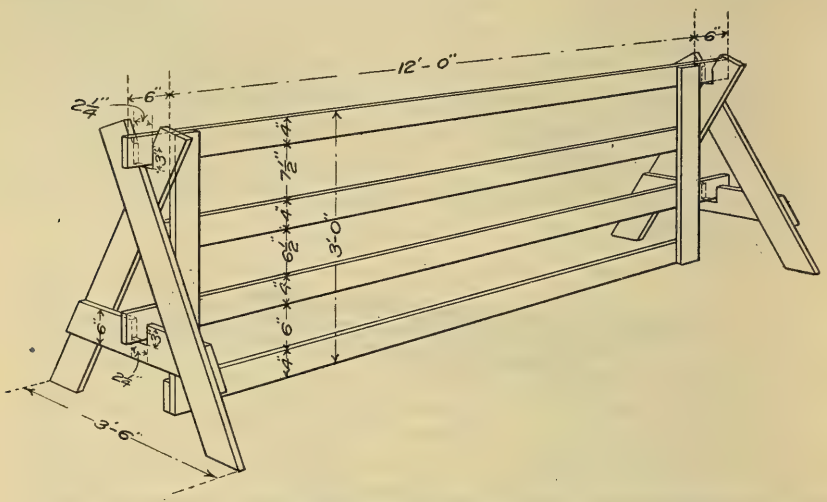

FIG. 2.—Panel and braces for making a portable sheep fence. Wire fencing is also frequently used in the construction of panels.

classes of sheep. A number of lots should be available for this. A chute, with a gate that swings either way, saves much time and

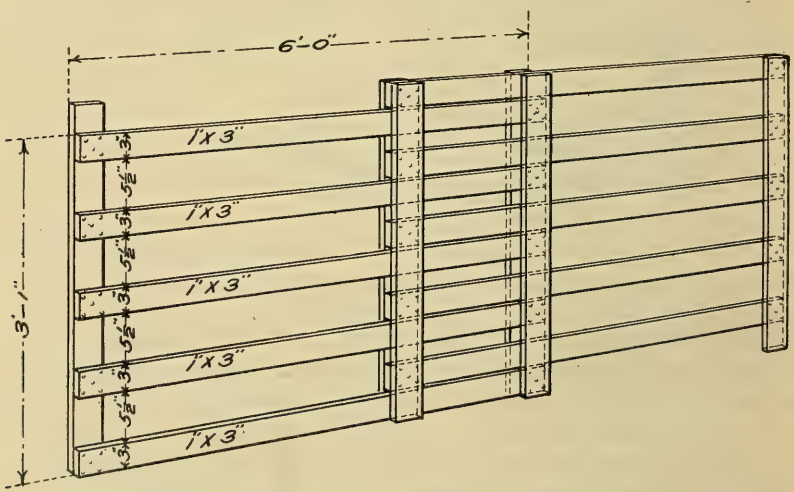

FIG. 3.—Extension hurdle; convenient for making temporary partitions in the pens. Can be closed up to 6 feet 4 inches or extended to 11 feet 4 inches.

trouble in separating the sheep. An arrangement of this kind is illustrated in figure 4.

FENCING.

The lots and pastures upon a sheep farm require considerable fencing. Lack of adequate fences has been one factor in the decline of the sheep industry in many localities. A woven-wire fence is the cheapest and most satisfactory, all things considered. If it must be dog-proof the meshes should be close enough together to prevent the dogs passing through, and it should be at least 5 feet high, which is a desirable height for all outside fences. Care should be taken in putting up the fence to see that the wire is close enough to the ground

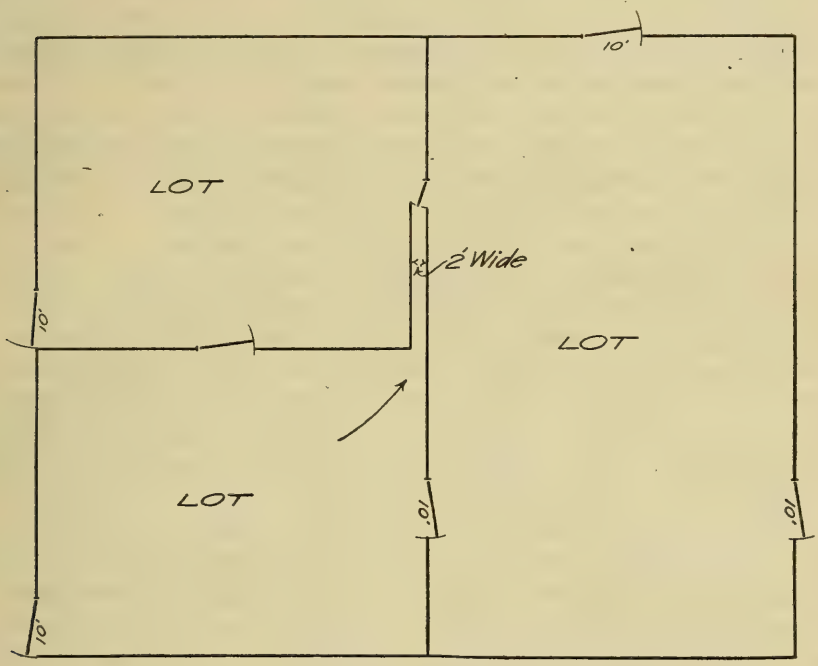

FIG. 4.—Convenient arrangement of sheep lots with sorting chute.

to prevent dogs from crawling under it. For temporary cross fences there are a number manufactured from 32 to 42 inches high. A 36-inch fence is very satisfactory and is used extensively. An advantage of wire fencing is that neither sheep nor dogs will jump it so readily. Barbed wire is undesirable, except at the top, because the sheep tear out their wool upon the barbs.

HOUSING.

It was formerly quite generally thought that the sheep's wool afforded it all the protection necessary during the winter. If the fleece could be kept dry it probably would retain enough body heat to keep the sheep warm, but this is impossible without shelter. When

a fleece once becomes wet it takes a long time for it to dry out, especially in cold weather. Much energy that would otherwise be used for growth or fattening must be used for evaporating this water. The wet fleece also gives rise to unhealthy conditions. In Great Britain little housing is necessary, but in most places in America this would result in undue losses.

Now that it is generally agreed that a certain amount of housing is necessary, the question arises as to what kind it shall be. This depends somewhat upon the locality and the product of the flock. If winter or early spring lambs are to be produced, the shelter must naturally be warmer and more pretentious than where late lambs are the rule. The breed may also affect the kind of shelter required, some breeds being more hardy than others.

The following conditions should be fulfilled as nearly as possible in a shelter for the flock. It should be located upon a rise of ground sloping away on all sides, or at least to the south and east. It should be protected from and should face the side least exposed to the winter winds. The floors should be dry; there should be plenty of ventilation, but also freedom from drafts. An abundance of light is desirable, as is convenience of arrangement, making necessary the least possible amount of work. There should be adjustable divisions forming pens for the different classes of sheep, and it is desirable to have a door leading to the outside from every one of these. The doors should be wide enough so that there will be no danger from crowding, which may result in broken-down hips and abortion. If the doors are closed at all, it should be only in very severe weather. Corners on posts and beams where the sheep come into contact with them should be rounded, so that the sheep will not rub their fleeces against them. From 10 to 18 square feet of floor space should be allowed for each breeding ewe and about 18 inches should be allowed at the feed troughs and hay rack. The quarters should not be kept too warm, or the sheep will be subject to colds and catarrhal conditions. The nearer these ideal conditions are fulfilled the greater will be the amount of feed that can be profitably used in the production of mutton and wool.

SHEDS AND BARNS.

Either sheds or barns are desirable under certain conditions. Sheds are less expensive, and where the flock is not too large they serve very well. Some of the best results have been obtained through their use. There is more work connected with caring for the sheep, as their feed will have to be brought from outside the shed, but this may be offset by the lower cost of construction. "Lean-to" sheds are commonly used upon the farm for sheltering the flock, and can be arranged very satisfactorily.

When a barn is built sufficient outlay is justifiable to make it convenient. Storage should be provided for roughage, grain, and roots. If the haymow is above the sheep it should have a tight floor, so that the hayseed and chaff can not fall down upon the sheep. The root cellar must be frost proof. Barns having two floors for sheep are sometimes built.

The barn should be cleaned out several times during the winter. Slaked lime, gypsum, or disinfectants scattered about dispel the odors that arise at this time. The pens should be bedded down whenever necessary, so that the sheep are kept clean and dry. Shavings are not a very satisfactory bedding material. They become entangled in the wool, and are troublesome in shearing. Wheat straw is the most satisfactory material for this purpose, though oat straw is very good. Ordinarily the refuse from the hay racks affords sufficient bedding. An attractive and desirable sheep barn remodeled from an old farm building is shown in Plate II, figure 2, the barn at the United States Morgan Horse Farm, at Middlebury, Vt.

CARE OF EWES.

Some time between weaning and mating the ewe flock should be culled over. They should be "mouthed," and any broken-mouthed ewes separated and fattened for the butcher. The age at which sheep lose their teeth varies with a number of things. They lose them sooner upon sandy soil than upon clay or loam. Ewes are culled out at 5 or 6 years of age as a general rule. Sometimes an exceptional individual can be profitably kept after this age; especially is this true of purebred ewes, which are frequently kept until 10 or 12 years of age. Such animals, however, require much more attention and such feeds as they can readily eat, if they are expected to continue useful. Barren ewes, those having defective udders, and those that are inherently poor mothers should also be culled out.

FLUSHING.

It has been the general belief for a great many years that having the ewes in a gaining condition at mating time increases the percentage of lambs. This is commonly known as "flushing," and is accomplished by turning the ewes upon rape or other such feeds after having been upon short pasture. Some authorities hold that keeping the ewes in a flourishing condition throughout the year is even more beneficial. However, after three years' observations upon Scottish flocks, F. H. A. Marshall[1] reported that some form of extra feeding immediately before the mating period appeared to increase the percentage of lambs. As to the other, we have no definite information. Having the ewes in flourishing condition also shortens the mating

[1] Trans. Highland and Agr. Soc. Scot., 5 ser., 20.

season and makes conception more sure. This is an advantage in that it shortens the lambing period. Having the lambs as near one age as possible is an advantage when they are to be sold, as uniform lots always sell more readily and at higher prices than uneven ones.

TIME OF MATING.

Some breeds of sheep mate at any season of the year, such as the Barbados. Others, such as Dorset, Tunis, and Rambouillet, mate either in the fall or spring, while the other breeds mate only in the fall. The time of mating depends upon the time it is desired to have the lambs dropped. With those that are bred in the fall, there is a growing tendency to have them lamb as early as possible, as the early lambs are not troubled so much with stomach worms. Where "hothouse" lambs are raised the ewes are mated in the spring or late summer. It is common among Dorset breeders to have most of the lambs dropped in the fall.

With ewes that lamb in the fall the rams are turned in during the months of April, May, and June, while with ewes that lamb in the spring they are turned in during August, September, and October.

GESTATION PERIOD.

The gestation period is the time between the effectual service of the ram and the dropping of the lamb when the ewe is in normal condition. The average has been found by the Wisconsin station,[1] in making observations on more than 1,200 ewes, to be between 146 and 147 days. The time varies somewhat with the individual and with its health and physical condition. The length of the period does not seem to influence the size of the lamb, but if lambs are carried from five to seven days overtime they are usually weak or dead when delivered. Ram lambs are usually carried for a somewhat longer time than ewe lambs and they weigh slightly heavier at birth.

SEPARATING PREGNANT EWES.

It is much better if the breeding ewes can be kept separate from the rest of the flock. They require special management and feeding, and this can be more easily done when they are in an inclosure by themselves. Abundant exercise should be given them. They should not be fattened, neither should they be allowed to become thin.

FEEDING PREGNANT EWES.

Turnips, rutabagas, and swedes are the most desirable roots for breeding ewes, mangels and sugar beets being undesirable before lambing. Frozen roots should not be fed, as it is claimed that they will cause abortion. Frozen or acid silage should never be fed to ewes

[1] Kleinheinz, Sheep management.

or any other class of sheep. Silage of good quality, however, is very desirable. Too large a supply of succulence should not be given ewes before lambing, or weak, unhealthy lambs may be the result.

Oats and bran are as good concentrates as can be secured. Corn alone is too fattening. Whether or not the ewes require grain throughout the entire winter, and the amount they will need, depends largely upon their condition and the kind of roughage and succulence fed. In the Willamette Valley, where abundant green forage is available throughout the year, practically no grain is fed before lambing. But under average conditions succulent forage of this nature is unavailable, and a little grain should be fed, beginning several weeks before lambing, to stimulate the milk flow. An average ewe's daily ration during pregnancy would be about as follows: Two to three pounds of hay, 2 pounds of roots or silage, and one-half pound to 1 pound of grain. Usually one-half pound of grain is enough before lambing if the ewes enter their winter quarters in good condition.

Turning the ewes out after they have eaten their morning feed for water and for a light feed of corn fodder or some similar feed is a good plan when the weather is not too severe. This gives them plenty of exercise and allows the troughs and racks to be readily cleaned out and the evening feed placed in them. Alfalfa, clovers, etc., are the most desirable roughage. Succulence in the form of silage or roots is essential for the best results, as experiments have shown that ewes receiving such feeds produce stronger lambs and have a larger milk flow. Thousands of breeding ewes have died in this country of "blind staggers" brought on by feeding timothy hay without succulence. This particular kind of hay causes constipation and is very undesirable for sheep.

LAMBING.

This is the busiest time of the shepherd's year. The forward ewes should be picked out and placed in a pen by themselves, where they are allowed to lamb. They should be looked after occasionally and aided if necessary. Generally it is not necessary to watch later than 11 o'clock at night, for if a ewe does not lamb before this time she usually will not before 4 o'clock the next morning. Many a ewe or lamb that would otherwise be lost may be saved by a little extra attention on the part of the shepherd. Malpresentation occurs occasionally in the best-managed flocks, and sometimes a ewe may have a lamb that is too large for her to deliver unaided. The normal presentation of the lamb is head first with the lower jaw resting upon the fore legs.

If the lamb is partially delivered under normal conditions, it can usually be helped out by grasping it with one hand by the fore legs and pulling at the same time the ewe strains. If the head or either

leg is back these must be worked forward before delivery can take place. Occasionally lambs are delivered backwards. In this case, if either leg is bent back the fetus must be pushed back and the hind legs pulled out first. If there are no indications of delivery and the lamb is considerably overdue it is probably dead, and it must be taken from the ewe if she is to be saved. Before doing this the finger nails should be closely trimmed and the hands and arms should be thoroughly washed in warm water containing from 2 to 3 per cent of some good disinfectant. If linseed oil is smeared about the passage the lamb can be removed much easier. The hand is inserted into the vagina until a hold can be secured upon the lamb, which is then slowly and gradually worked out, front feet and head first if possible. When it is necessary to remove a lamb in this manner, the ewe should be thoroughly washed out with warm water containing a little disinfectant. This can best be done by means of a small rubber hose and funnel. Some one who has had experience should be on hand in a case like this, as conditions are constantly arising that can not be guarded against by written instructions. If the ewe be a valuable one, it may be advisable to secure the services of a veterinarian.

CLAIMING PENS.

After lambing, the ewe and her lamb, or lambs as the case may be, should be placed in a claiming pen if she refuses to own her offspring. If left loose the lamb wanders about, becomes lost among the flock, and loses its characteristic smell by which the ewe recognizes it. She will then refuse to claim it, and the trouble begins. By placing them by themselves all of this is avoided and a closer watch can be kept upon them to see that all is well. The length of time they should be kept in the pen will depend upon how long it takes the ewe to become reconciled to her lamb. Usually two or three days are sufficient. If the ewe persists in butting the lamb away, she should be tied so as to allow the lamb to suck. This soon brings about agreeable relations between them.

There are two types of pens, temporary and permanent. Temporary pens are conveniently made of some light material and consist of two sides that are hinged together and set up in a corner of the barn by the use of hooks (see fig. 5). Rows of these can be placed along the sides, if necessary. They have the advantage that they take up little room and they can be removed when not in use.

Permanent pens are more desirable in a number of ways. For example, the ewe is more completely isolated from the other members of the flock and consequently becomes reconciled to her offspring sooner. These pens should be about 4 feet square and boarded up tightly so that the ewe can not see the rest of the flock. Lambing pens, in which the ewes are placed before they lamb, are used to some

extent. They are objectionable, however, in that they cause the ewe to become restless and dissatisfied when removed from the flock, which is especially undesirable at this time. If they are so constructed that the ewe can see the other members of the flock, this will be partially remedied.

FEEDING AFTER LAMBING.

After lambing, the quantity of roots or silage and of grain should be gradually increased. The grain ration may be increased to 2 pounds per day, if necessary. In exceptional cases, more than this amount has been fed. After the flock is turned out to pasture and

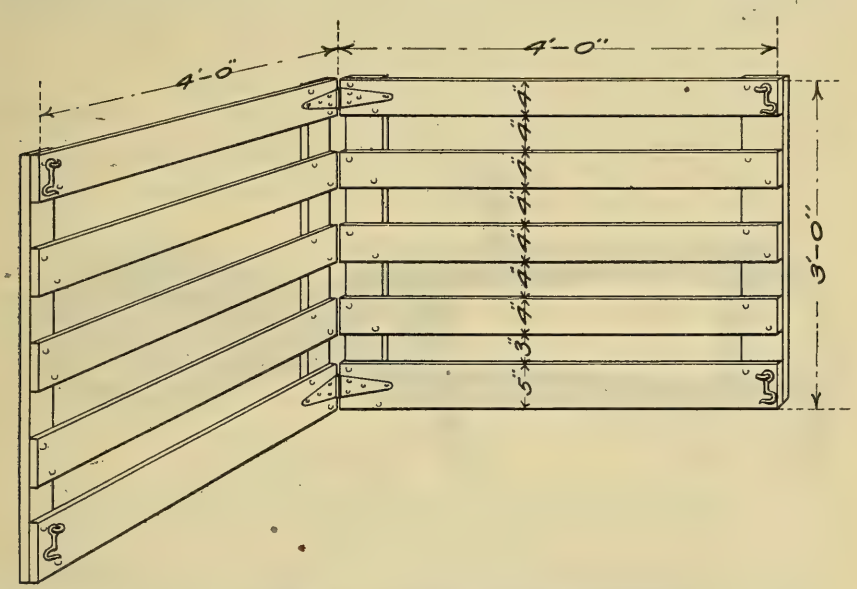

FIG. 5.—Hinged panels for temporary lambing or claiming pens.

the freshness is worn off the grass there is little benefit in feeding grain to ewes, so far as the lambs are concerned. The only difference that it makes is that the ewes do not lose so much flesh. During the summer, if the pasture has become short and parched, additional forage may be necessary. Rape, oats and peas, and green corn are to be recommended for this purpose. During weaning, however, it is advisable to put the ewes upon scant pasture to check the milk flow.

TAGGING EWES.

Returning to the general management of the flock other than feeding, the ewes should be tagged shortly before lambing. This is merely the clipping off of the filthy locks of wool from the hind quarters. The wool should also be trimmed away from the teats so

that the lambs can suck without getting it into their mouths. Swallowing wool frequently causes death, as many as 50 wool balls having been found in one lamb.

Sore teats and udders are of rather common occurence among ewes suckling lambs. Where an inflamed condition has arisen, the udder should be milked out, bathed in warm water, and treated with some antiseptic ointment that will not injure the lamb if taken into its stomach. Carbolated vaseline is excellent for this purpose.

EWES THAT HAVE LOST THEIR LAMBS.

Sometimes it happens that a ewe loses her lamb. If she has a good milk flow, she can be taken care of most readily by giving her a lamb from a ewe that has no milk or from one that has had twins. Several methods have been used for making such a ewe claim her lamb. Among these are, tying up the ewe so she can not butt the lamb about, sprinkling some of her milk over the lamb, and placing the skin of the dead lamb over the one to be adopted.

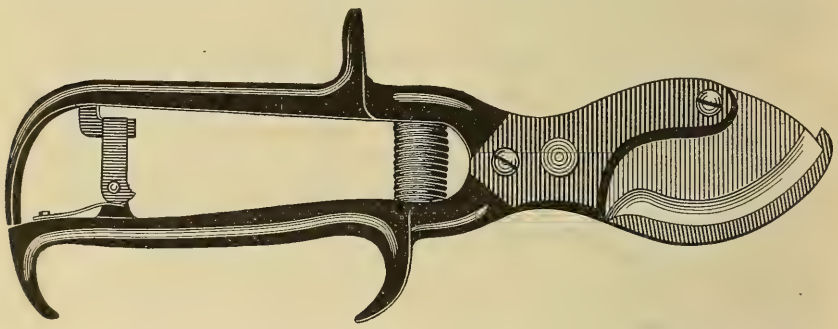

FIG. 6.—Pruning shears or sheep toe clippers used in trimming the feet and also for docking lambs.

SHEARING THE EWES.

Under ordinary conditions, shearing the ewes should take place after lambing. It is also desirable to shear them before turning out to pasture. Otherwise the wool becomes unnecessarily dirty and the ewes remain outside in weather that is too severe for the lambs. Unfortunately, this is not practiced in many flocks. Shearing before lambing is practiced where the ewes are to lamb late, but it requires much more care and experience in handling them, and it is necessarily much slower than shearing afterwards.

TRIMMING THE FEET.

The feet of the entire flock will ordinarily need attention about twice a year. The hard outer shell grows under the soft part of the feet, inclosing more or less filth and making it difficult for the sheep to walk. This superfluous growth should be trimmed away and care must be taken not to cut back too far into the tender parts. Pruning shears, such as are used in docking lambs and trimming small shrubs are valuable for this purpose (see fig. 6). A sharp knife can also be

used to good advantage. Either before or after shearing is an excellent time for giving the feet attention.

DIPPING.

Not only the ewes but the entire flock should be dipped shortly after shearing. They should not be dipped either in extreme hot or cold weather, and if the weather is unfavorable immediately after dipping, protection should be provided them. If dipping is done while the wool is short, it will be more quickly and thoroughly done, less material will be required for the dip, and the wool will dry out quicker. A satisfactory sheep dip is one that will destroy ticks, lice, scab, and all external parasites, and yet will not injure the skin or wool. There are a number of good dips upon the market which are

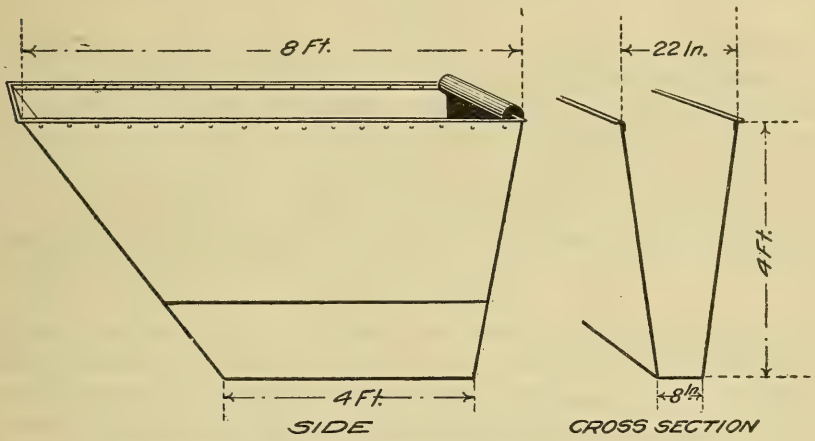

FIG. 7.—Outline of metal dipping tank suitable for the ordinary farm flock.

recognized by the United States Department of Agriculture, any one of which will give satisfaction if directions are carefully followed. It is claimed for some of these that they are an actual benefit to the skin, in that they act as a stimulant.

If the flock is badly infected with scab, it becomes necessary to dip twice, with an interval of ten days to two weeks. The second dipping destroys those parasites that were in the egg stage at the time of first dipping.

A dipping tank should comprise part of the equipment for every flock. They are constructed of galvanized iron, concrete, and wood. A galvanized-iron tank, such as can be purchased upon the market, has several advantages. It is light enough so that it can readily be moved from one place to another. Several farmers can own one in partnership. With the ordinary flock a small tank, such as shown in figure 7, will answer the purpose. Details of a concrete dipping vat suitable for large flocks are given in Farmers' Bulletin 481.

ATTENTION TO EWES AFTER WEANING.

The ewes should be watched carefully for a few days after the lambs are taken away. Most of them, especially the heavy milkers, will have to be partially milked out a few times. Some will not have to be milked more than twice, others perhaps four or five times. As the period of drying up progresses, gradually increase the time between milkings. A ewe can be quickly milked by backing her up against a fence so that she can not go backwards, and pressing the knees against her shoulders so that she can not go forward. Both hands can then be used. Ewes can also be milked out conveniently by setting them upon their rumps, as the operator can see better what he is doing. Inflammation and caked udders are the result of inattention at this time, and the best ewes of the flock suffer most.

CARE DURING REMAINDER OF SEASON.

The time between the weaning of the lambs and mating should be a "resting up" season for the ewes. As a rule they have lost more or less flesh in nursing the lambs, and their systems need toning up. This can best be brought about by an abundance of good pasture, pure water, and shade. Frequent changes of pasture are essential for best results. The flock should be aided in every way in regaining lost vitality, and put in a flourishing condition for the next season's work.

CARE OF LAMBS.

Spring lambs should come early enough so that they will be old enough to eat grass when the ewes are turned out to pasture. Early lambs seem to have more vigor and vitality and they seem better able to resist the attacks of parasites than late ones. They entirely escape most of the ills common to young lambs, consequently they make more rapid growth and thrive much better. For these reasons it is best to have lambs come early.

REVIVING WEAK LAMBS.

Sometimes a lamb is born very weak and seems almost dead when delivered. It may not even be breathing. The phlegm should be cleaned out of its mouth and nostrils and artificial respiration started. This may be done by breathing into the lamb's mouth three or four times, then holding it with one hand upon its belly, patting it with the other just back of the shoulders. It may be necessary to repeat the operation three or four times. Many apparently lifeless lambs have been revived in this way.

HELPING LAMBS NURSE.

It is often necessary to help the lamb nurse the first time. It may be unable to find the teats itself or the ewe may refuse to allow it to suck. After helping it a few times it is usually able to take care of itself.

CHILLED LAMBS.

Lambs should never be allowed to become chilled, but sometimes it is unavoidable owing to the ewe lambing unexpectedly. When chilled the lamb should be given a bath as quickly as possible in water as hot as the hand can bear. It should then be rubbed dry, a dry rag wrapped about it, and removed to a warm place. A box of warm, dry bran is a good substitute for the rag used in wrapping. A half barrel bedded with straw in which a jug of warm water is placed is also convenient. A few drops of whisky in a little warm water makes a good stimulant for the lamb for such occasions. Constipation commonly follows chilling, and it should be guarded against. Castor oil should be given if this condition arises.

PINNING.

Pinning of the tail sometimes bothers the young lambs before they are docked. Diarrhea or a loose condition of the bowels causes the tail to be plastered down to the hind quarters and a foul condition results. Scraping or washing off the collected feces with warm water relieves this condition.

RAISING LAMBS BY HAND.

If a ewe dies or if she is unable to supply her offspring with sufficient milk, it becomes necessary to raise the lamb by hand. Cow's milk, while it is not as rich in solids as ewe's milk, serves as a very good substitute. The milk from the same cow should always be used, and she should be one that has recently freshened. The milk should be heated to about 92° to 94° F., but should never be boiled, as this causes constipation. The lamb may be fed with a spoon for the first few times, but this is too much trouble to continue for any length of time. A nursing bottle with an ordinary nipple is convenient. The secret of success in raising lambs by hand is in having the milk at the right temperature and not boiling it, in feeding often, every hour or two at first, and in having the utensils scrupulously clean.

MARKING.

Marking with labels.—Every sheep of the flock should be marked, and there is no better time for doing this than when they are lambs. If possible they should be marked the day dropped and then there will be no danger of their being confused. Lamb-size labels are sometimes used, being replaced with the regular-size labels at weaning time. It has been said that using the sheep-size labels upon young lambs causes their ears to droop, but some experiments carried on at the Wisconsin station indicated that such is not the case.

The breeder's label is first inserted. It should have upon it the flock number and initials or name of the owner. The most popular label is a metal band, and it has not only been adopted by most of the

breeders but also by the leading breed associations. The association labels have stamped upon them the abbreviation of the breed association and the registry number.

The tag should be placed in the lower part of the ear, fairly close to the head, with the number on the inside. The label should not be too loose or it is more likely to be torn out. Neither should it be too tight or it may damage the ear. Sometimes the ears become sore from inserting the labels, especially if the operation is carelessly performed. Occasional attention should be given the lambs after

FIG. 8.—Methods of marking sheep: *a*, Ear label; *b*, notching; *c*, tattooing.

inserting the labels to insure their ears healing properly. The one objection to ear labels is that they may be torn out. The ear label is illustrated in figure 8, *a*, and the punch for inserting it in figure 9. The latter may also be used for notching.

Notching.—Notching is a good way to mark sheep, and it is quite frequently used. Notches upon certain parts of the ears indicate certain numbers, the sum of the numbers represented by the notches being the number of the sheep. By a series of notches any numbers desired for the farm flock can be obtained. The system is shown in figure 8, *b*. Numbers up in the hundreds involve a rather complicated system, but these are not usually necessary on the farm. To avoid a complex system, each crop of lambs may be numbered from 1 upward. In this way it will not generally be necessary to notch higher than 100. This system is sometimes used as a check for ear tags in case the latter become torn out.

FIG. 9.—Punch used for inserting ear labels. Can also be used for notching.

Tattooing.—Tattooing on the inside of the ear is a satisfactory way of marking sheep, especially those having light-colored ears (see fig. 8, *c*). Special tattooing instruments are upon the market for this purpose having adjustable numbers and letters, with which a combination containing three or four of either or both can be secured. This is another good method of checking on the ear label. India ink, both stick and liquid, special tattooing oil, and indigo can be used for

pigment. The Department of Agriculture has had excellent results with all of these. Breeders sometimes tattoo their initials in the ears of all their sheep so as to eliminate any question of breeding.

Branding.—Branding is a common way of marking sheep in the West. It is done with branding paint upon the wool or with a hot iron upon the nose. Branding with paint upon the wool is the most common method. The paint brands are stamped upon a prominent place so that they can be readily seen; either on top of the shoulders, on the back, or on the rump. Quite often lots of sheep that are to be kept separate are branded some number in order that they can be readily identified if they become mixed. Different-colored branding paints are used, the more common being red and black. The brands are made of either wood or a small iron rod about three-eighths of an inch in diameter. Branding paints can be purchased upon the market ready for use, or they can be prepared upon the farm.

The disadvantage of branding lies in the difficulty of securing a paint that will remain legible throughout the season and yet scour off readily in the scouring processes of the wool. When the brands must be clipped off by hand the resulting loss of wool and labor is considerable. Branding with a hot iron is sometimes used in the range country because it makes a permanent mark, but this method is rarely, if ever, practiced upon the farm. Burning a brand upon the horns is used to some extent, but this method has been used more in foreign countries than in America.

CASTRATION.

It is surprising how many native lambs come to market without having been castrated. The operation is an extremely simple one, and the financial losses that result from failure to perform it are considerable. A ram lamb develops sexual characteristics at about three months of age. They then become restless, worry the rest of the flock, and fight among themselves and cause a generally unsatisfactory condition. They cease to make satisfactory gains themselves, and prevent the other members of the flock from doing so. The following experiment[1] was conducted to determine the difference in gain between ram and wether lambs. Two uniform lots, so far as breeding and age were concerned, of 12 each, were selected, one lot being castrated, the other left entire. Both received the same feed and treatment, yet at the end of the feeding period the rams weighed 900 pounds and the wethers 1,020 pounds.

In another instance[2] statistics secured from several years' observation upon a flock showed that wether lambs gained in 60 days on

[1] Abstract Experiment Station Record.

[2] Proceedings of the Society for the Promotion of Agricultural Science, pp. 163–165, 1901.

an average 2.25 per cent in live weight and 4 per cent in dressed weight more than did the buck lambs.

The bucks become coarse as they grow older. Their increase in weight is confined more to the fore quarters, neck, and head, which are the lower-priced parts of the carcass. Their frames are coarser and they do not have as deep a covering of flesh. Wether lambs, on the other hand, develop more in the loin and back, the region of the high-priced cuts. For these reasons ram lambs are sharply discriminated against as soon as sex character develops, and, generally, the older they are the sharper is this discrimination.

Upon the Buffalo market the difference in price between ram and wether lambs has ranged from $0.65 to $1 per hundred pounds in the same month in favor of the wether lambs. Quite often ram lambs grade as culls and sell for as much as $2 per hundred pounds less.

Ram lambs can not be profitably kept to wait for favorable market conditions, as they cease to make satisfactory gains after they have reached a certain age. Another reason for unsexing all ram lambs not desired for breeding purposes is that there is danger of getting the ewes in lamb to the poorest one in the flock. The ewe lambs are also often pregnant under these conditions when they arrive on the market, which is another objectionable feature.

Age of castration, methods, etc.—Castration should be done when the lambs are from 2 to 4 weeks old. If they are allowed to become older the operation is more severe. The quarters should be as clean as possible for the operation. One of the best methods is to cut off the lower third of the scrotum with a clean, sharp knife, and force the testicles down. They can be grasped by the thumb and two fingers and pulled out, one at a time, with the spermatic cords attached. If the lamb is rather old and the cords will not pull out, they can be cut or scraped off above the testicles. Many shepherds use their teeth for drawing out the testicles, but this is a disagreeable practice to many people. A pan of clean water containing a 2 to 3 per cent solution of some good disinfectant should be used by the operator in washing his hands and the knife, and the wound should be disinfected after the operation. Ointments, such as carbolized oil (20 parts sweet oil, 1 part carbolic acid) and pine-tar salve (equal parts pine tar and pure hog lard), are also recommended for dressing the wounds, but it is impracticable to use disinfectants or ointments when the flock is large.

Lambs are sometimes unsexed by cutting off the scrotum close to the belly with heated shears or with a special emasculator, but this method is not very satisfactory. It is seldom advisable to castrate an aged ram; the difference in value of the carcass is scarcely worth the trouble.

DOCKING.

There are a number of good reasons for docking a lamb, any one of which would warrant the operation. Practically the only use of the tail to the sheep is to protect the rearmost parts from flies. Docking is a cleanly practice; undocked sheep become very filthy and are likely to become infested with maggots. They bring a lower price upon the market because of the dirt and manure they carry and because of their uneven appearance. Docked lambs appear more blockly, and ewes that are docked are served by the ram more readily than undocked ones. The operation should be performed when the lambs are from 1 to 2 weeks old. Only winter or "hothouse" lambs, or those sold early, should not be docked.

Methods.—Hot pincers, pruning shears (see fig. 6), a sharp knife, and a chisel and block are all used in docking. Pincers (see Pl. III, fig. 2) are made especially for this purpose and are heated to redness before being used. On the ranges, where there are several men to catch and hold the lambs, from 15 to 35 tails can be docked with one heating. Reasonable care should be exercised in using these instruments. The principal advantages in their use are that the work is quickly and neatly done and that there is no loss of blood. Once this system is adopted no other is likely to be practiced.

Pruning shears are quite frequently used in docking and are satisfactory, especially when the lambs are docked young, before the wool has attained much growth upon the tail. The knife is the most common docking instrument upon the farm. The main objection to its use is that it may cause excessive bleeding. The chisel and block are used to a limited extent.

GRAIN BEFORE WEANING.

Usually lambs will begin to nibble grain along with their mothers when from 10 days to 2 weeks old. The amount of grain and the kinds that should be fed before weaning will depend upon the purpose for which they are intended. Hothouse lambs should be forced as rapidly as possible, hence should be given all the grain they will consume. Such feeds as corn meal, cracked corn, oats, bran, middlings, and oil meal are most commonly fed to this class of lambs. Corn should comprise a large part of the ration.

Spring lambs for slaughtering purposes should usually be fed heavier than those intended for the breeding flock. The Wisconsin station found that lambs fed grain from birth attained a given weight from four to seven weeks earlier than those receiving no grain before weaning, and required no more grain for the same amount of increase. Higher prices are usually obtained for lambs early in the season, and where the lambs have been fed grain from birth they are usually in higher condition and can be sold at any time when market conditions

are most favorable. The largest and most economical gains are made during the first few months of a lamb's life.

It is generally profitable to feed a small quantity of grain before weaning to all classes of lambs. They grow faster, attain a larger size, become more robust, escaping the ills that beset the slow-growing or stunted lamb. Where grain has been fed from the first the demands are not so heavy upon the ewe, and the lambs do not feel the effects of weaning as much as they otherwise would.

The average amount of grain per lamb per day should vary from one-fourth to one-half pound. The ration should be very light at first and should be gradually increased. Ordinarily, more than one-half pound per day will not increase the gains, but will lessen the amounts of pasture consumed by the lambs. Two parts bran, two parts oats, and one part cracked corn makes an excellent grain ration for growing lambs. Roots and alfalfa can also be fed to young lambs to advantage.

LAMB CREEPS.

The lambs should not eat with the ewes, but should have their grain separate. A lamb creep is necessary for this, and with it there is the advantage that the lambs can eat whenever they care to. A lamb creep is simply an inclosure, containing feed troughs, with openings large enough to permit only the lambs to enter. Rollers on the sides of the openings are much superior to slats, as they allow the lambs to enter through smaller openings, and with less danger of scraping their sides. A good type of lamb creep is shown in Plate IV, figure 1.

WEANING.

Weaning should take place when the lambs are 3 to 5 months old, depending upon the time they are dropped. After separating the lambs, they should be turned into a field at a considerable distance from the ewes, where there is good pasture. Where the lambs have been encouraged to eat previously, separating is merely the last step of weaning, and the lambs scarcely notice the change.

CARE AFTER WEANING.

After weaning, the lambs should continue having such feed and care as will continue their growth. A stunted lamb never makes up its lost growth, no matter how favorable circumstances may be afterwards. It generally pays to feed a little grain all through the summer. If they are to be fattened later the grain-fed lamb makes more rapid and economic gains than the one that has received no grain until the fattening period. There is little danger of getting lambs that are intended for breeding purposes too fat, unless an excess of fattening feeds are fed. The extra food they consume is used for

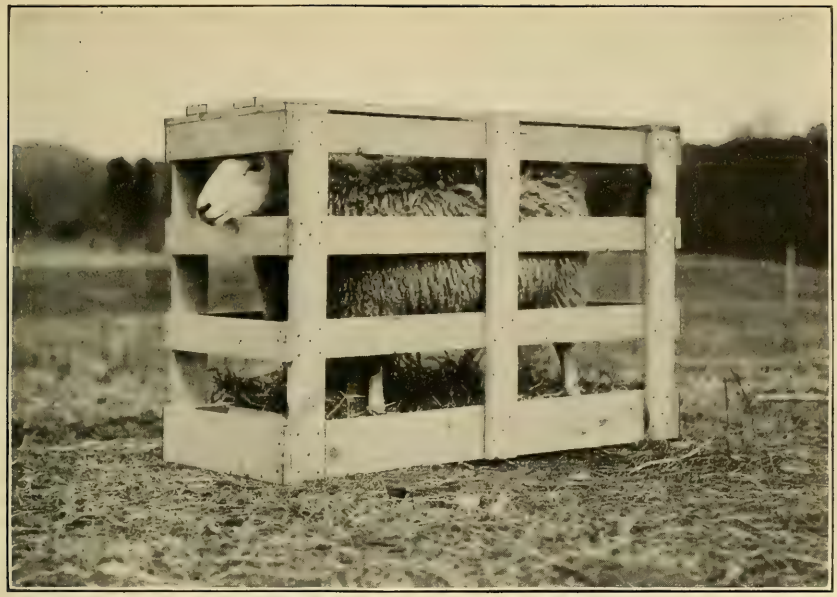

FIG. 1.—SHEEP CRATED FOR TRANSPORTATION.

FIG. 2.—METHOD OF DOCKING LAMB WITH HOT PINCERS.

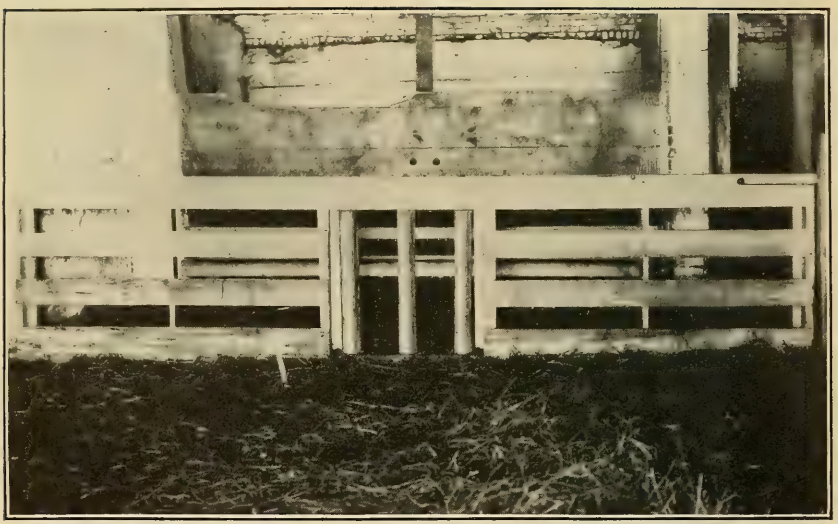

FIG. 1.—GOOD TYPE OF A LAMB CREEP, SHOWING THE USE OF ROLLERS.

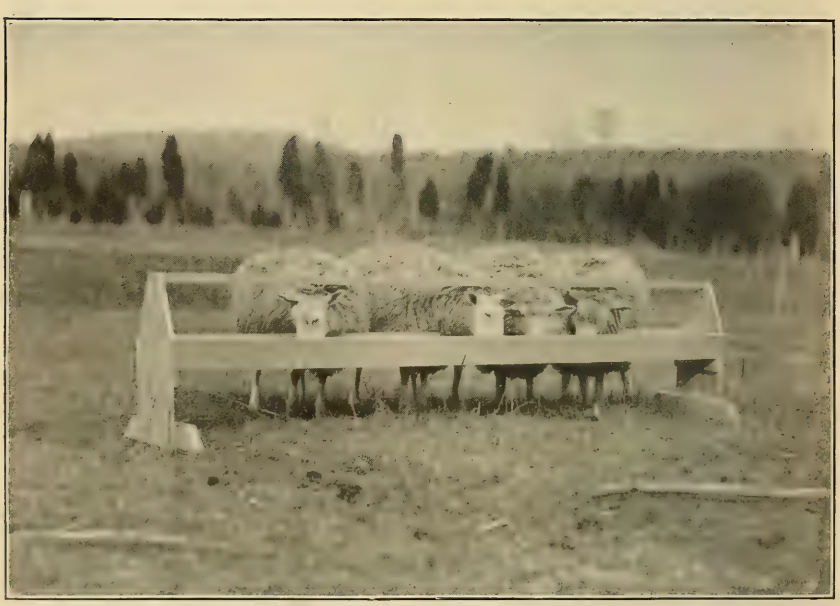

FIG. 2.—TYPE OF TROUGH AS SHOWN IN FIGURE 15 IN USE.

more rapid growth, rather than storing up fat. Forage crops, such as rape and kale, make excellent fall pasturage for lambs, and where the lambs have such pasture they may need no grain.

SEPARATING THE RAM LAMBS.

The ram lambs should be separated from the ewe lambs when not older than 6 months. Where there are a number of these, they had better be separated when weaned.

CARE OF RAMS.

It is desirable that breeding rams be in strong condition before and during the breeding season. Because of the extra demands made upon them at this time they should be given extra grain in addition to their regular ration, beginning about a month before mating and continuing throughout the season. A mixture of equal parts of bran and oats is as good a grain ration as one can desire. This feed keeps the ram vigorous and does not induce fattening.

CARE DURING MATING SEASON.

Many farmers allow the ram to run with the ewes throughout the year, but this is a poor practice. It is much better to turn the rams in only during the breeding season, and this is the ordinary method. With many purebred flocks the rams are turned in only during the night.

It is good practice to paint the brisket of the ram every two weeks with a different colored paint, that will rub off on the ewes that are served. In this way the approximate time of mating can be determined, and also whether or not the ram is a sure breeder. A close watch should be kept upon an untried ram to determine his breeding qualities, as an infertile one, if not detected, will cause the loss of a lamb crop. One ram will cover the average farm flock, but it is advisable to have a second one, if the flock will warrant it, to use in case the stock ram proves a nonbreeder. From 30 to 40 ewes are covered by a ram where allowed to run with the flock.

Hand coupling.—Hand coupling is a very satisfactory way of handling the ram where the flock is not too large. It is often practiced in purebred flocks. With hand coupling the most practical way is to drive the ewes into a small lot in the morning and turn the ram in with them. He soon singles out a ewe that is in heat and as soon as he has served her she is removed. Two or three ewes can thus be served in the morning and as many more in the evening, after they have again been driven up.

Some shepherds turn in a teaser with the flock to single out the ewes that are in heat. An old ram with a gunny sack tied over his

belly to prevent his serving the ewes is commonly used for this purpose.

Hand coupling is superior to allowing the ram to run with the ewes, for the following reasons: One ram can cover more ewes because he is prevented from devoting all his attentions to one, and his energies are conserved by permitting only one service. The exact date of service can be kept, and an infertile ram can be detected much easier. As many as 100 ewes have been covered by a single ram with this method. The one objection to the practice is that it takes considerable time.

The length of the breeding season depends upon the time of the year. For instance, if rams are turned in with ewes during the months of August or September, the season would be much longer, owing to the fact that not so many of the ewes are likely to be in heat at this time. The season should be long enough so that the ewes can return in heat, if they do not become pregnant at the first service. The duration between periods of heat in a ewe ordinarily ranges from 14 to 18 days. In exceptional cases 21 days have elapsed between periods.

CARE AT OTHER TIMES.

During the winter the ram should receive enough grain to keep him in good condition. Clover or alfalfa hay makes good roughage, and silage or roots, such as turnips, swedes, and rutabagas should form the succulent part of the feed. Sugar beets or mangel-wurzels should never be fed to rams. They cause the formation of calculi in the kidneys and bladder, and stoppage of the urethra, and the bladder is often ruptured as a result. Many good rams have died as a result of their being fed these roots.

Where there is but one stock ram, he can be used only two seasons without inbreeding, but where there are several they can often be kept longer. In either case the rams should be well taken care of, and they can often be disposed of to good advantage to some other breeder. In this way, inbreeding will be avoided and the flock can be managed with little increased expense for rams.

CARE OF STORE SHEEP.

Ewe lambs that are intended for breeding purposes the following season should be separated from those lambs intended for the butcher before fattening begins. It is essential that the breeders should be kept in good growing condition, but it is unnecessary, and even undesirable, to have them fitted as highly as the market lamb. Neither should they be allowed to run with the breeding ewes during the winter, as their feeding requirements are somewhat different. If good roughage, such as alfalfa, or clover and roots, or silage, is

available, little grain need be fed during the winter, though a small amount may be desirable. If waste roughage is fed, more grain will be necessary. During the following spring and summer good pasture should be sufficient in itself, at least until flushing is practiced.

Holding over wethers is not a very common practice in the farming sections, nor is it a very profitable one, but there are some sections where it is done. Much waste roughage can be consumed by them, but they should not be allowed to subsist entirely upon these. It never pays to allow a sheep to become poor in condition, especially when growing. They can be maintained in good condition upon less feed than will be used in fattening them after they have been allowed to become thin. Good pasture should be sufficient for wethers during the summer season, and they may be partially fattened on grass. Wethers should never be fed mangel-wurzels or sugar beets for the same reasons previously mentioned for rams.

Ram lambs not used for breeding purposes should not receive as much grain as stock rams, but they should be kept gaining all the time. If these rams are to be sold, they should be kept in good condition, as well as attractive in appearance, as this adds materially to their ease of disposal and to the price obtained for them.

FEEDING SHEEP.

REGULARITY AND UNIFORMITY.

After sheep are fed a few times at a certain time of the day, they become accustomed to being fed at that time and will make their best gains only when regularity in feeding is practiced. Half an hour before feeding time the flock will be quiet, probably lying down. Within a few minutes of the time they are to receive their feed, they will come up to the gate or feed troughs and wait for the feeder. They soon become impatient if he does not appear, and much of the benefit of the feed is lost. Quiet and contentment are conducive to the largest gains and the best health of the flock.

Much of the same is true about the amounts of feed. Uniformity in this respect should also be practiced. A rapid change in the amount and kind of feed frequently results disastrously to sheep.

CLEANLINESS AND VARIETY.

Sheep are very particular about the feed they eat. They will not touch feed that has been "nosed over" by other stock, nor do they relish feed from filthy troughs. The troughs should be cleaned out before each feeding and they should be kept dry. Sheep in their primitive state were of a roving disposition, nibbling a little here and a little there. In this way they secured a variety of feeds. Under domestic conditions they should still receive as much of a variety as possible.

RETURNS FOR FEED.

In economy of production sheep are not surpassed by any other domestic animal. Besides converting waste products into nutritious food, they will also manufacture a finished product out of the roughage and grain of the farm at least as cheaply as other classes of live stock.

EXERCISE AS AGAINST CONFINEMENT.

Exercise is necessary for the natural development of the sheep. The different parts of the body must be used if they are to attain their highest efficiency. Hence, it is evident that the breeding sheep should have abundant exercise, even though it requires more feed. With market stock, however, the proposition is an entirely different one. In fattening lambs or sheep for the butcher, immediate results are sought and the farmer is not concerned with anything beyond securing the best animal for market purposes. Exercise sharpens the appetite and it also dissipates energy. Sheep that are exercised while being fattened eat their feed cleaner, and as a rule eat more of it, but in most of the experiments along this line they required a larger amount of feed per hundred pounds of gain than those receiving no exercise.

SHELTER COMPARED WITH OPEN FIELD FEEDING.

Since shelter is necessary for the best health of the flock, it is natural to suppose that larger gains will be made from a definite amount of feed when fed to sheltered sheep than from a similar amount fed to unsheltered ones. The protection offered by the shelter makes the sheep more comfortable and makes unnecessary the wasting of a considerable portion of the ration for keeping up the vitality of the sheep. Clean, airy sheds are undoubtedly superior to open lots for feeding.

GAINS AS AFFECTED BY SHEARING.

The effect of shearing upon the gains of fattening sheep is a subject that has occasioned considerable comment. The actual value of the practice depends upon the time of shearing, the condition of the sheep when shorn, the length of the fattening period, and the climatic conditions. When sheep are shorn in the fall, before cold weather, slightly larger gains can be secured than when unshorn, but except under the most favorable conditions it is doubtful whether the gains are large enough to be of very great importance to the farmer.

FEEDING FOR WOOL.

The best advice to be given in feeding for wool is to give such feeds as will completely nourish the sheep and to give them in such amounts and in such a way that the sheep will be kept in uniformly good condition throughout the year. The wool is an index to the physical

condition of the sheep. Disease or a change in condition are reflected in a weak place in the fiber, known as a "break." The same causes may effect a lack of luster in the wool, with the accompanying dead appearance that is undesirable.

An abrupt change of feed may cause sheep to lose their wool. For instance, sheep that have been raised upon grass, if fed a heavy grain ration without having gradually become accustomed to it, may shed their fleeces.

FEEDS.

It is practically impossible to give a definite feeding value to any particular feed. The value varies widely under different conditions. A certain feed will give quite different results when fed in connection with other feeds than when fed by itself. It may serve excellently as a partial ration, while it is altogether unsatisfactory for a total one. It may be rich in carbohydrates and fats, for instance, but lacking in protein, which is equally essential.

The digestibility of a feed is also influenced by the other ingredients of the ration, and this might affect its feeding value. Again, a feed may be too dense or too bulky, too dry or contain too much water to be suitable alone.

Neither is it practical to advise the particular kinds of feed, unless acquainted with local conditions. In the Middle West corn can often be fed profitably to a greater extent than elsewhere, because the transportation charges are unimportant. The same might be true of the cottonseed products of the South. Thus it is evident that the economy of a feed varies with the locality. However, there are certain groups of feeds some of which are essential for the best results with sheep. It is worth while mentioning these groups, leaving it to each farmer to select those particular ones best suited to his own conditions.

ROUGHAGE.

For roughage alfalfa, alsike, red-clover, cowpea, and similar hays are undoubtedly superior. Feeding tests in various parts of the country indicate that there is little difference in value between these forages, all of them giving excellent results. Corn stover, nonleguminous hays, and the various straws have been fed, in many cases with good results. Quite often these may profitably form a portion of the ration, but as a sole roughage they are inferior to the legumes. Timothy hay and millet are undesirable roughage for sheep; the former causes constipation and the latter often produces scouring.

METHODS OF FEEDING.

It is hardly necessary to say that there is less waste when roughage is fed in racks rather than upon the ground. When fed in the latter way much of it is trampled upon and soiled and the sheep then refuse to eat it.

There are several types of feed racks that are quite satisfactory. A combination rack for feeding both roughage and grain is convenient, especially where the amount of space is limited. Some racks are boarded up solidly, with openings through which the sheep eat; others are slatted horizontally, this type being largely used in the West. Racks with vertical slats are also used; these slats should not be too wide apart with suckling ewes or the lambs will get in upon the feed and soil it. Having the upper part of the rack boarded solid is desirable, as it prevents chaff from falling into the fleece. The arrangement and dimensions of various types of racks are shown in figures 10 to 13, inclusive.

PASTURE.

The sheep pasture should be well drained or foot rot will prove troublesome and the flock will not keep in the best of health. If

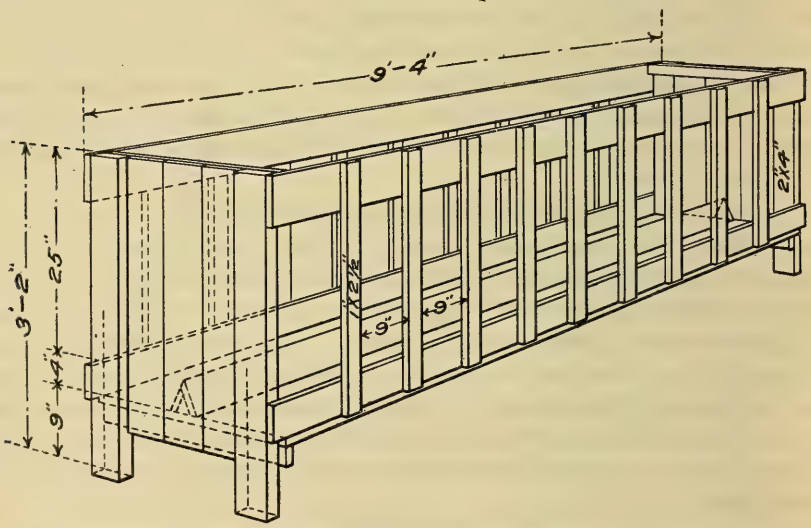

FIG. 10.—Combination rack for feeding hay and grain. Sheep can feed from either side.

the texture and structure of the soil of level fields is such that the rainfall is readily drained away, they may prove good feeding grounds, but as a rule rolling or hilly land is much better. Plenty of pure water is necessary and abundant shade is desirable, especially during hot weather, but sheep should not be allowed to lie under trees where manure has accumulated.

Avoid overstocking the pasture. If the sheep are too numerous they will eat the very roots of the grass, killing it and reducing the carrying capacity of the fields. Understocking is likewise undesirable, as it results in coarse, rank herbage that is not readily eaten by the sheep. Burrs and weeds that are not eaten should be destroyed, so that the seeds will not get into the fleeces.

Dead furrows are dangerous in a sheep pasture and should never be left open. Ewes rolling over into them upon their backs can not

rise to their feet unassisted, and most perish, if not discovered. The broadest-backed ewes are the most apt to suffer. Many a good one

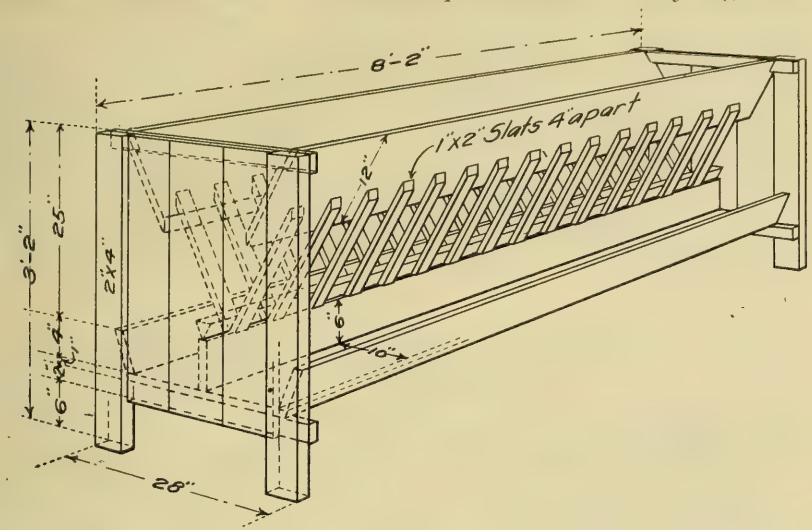

FIG. 11.—Combination rack for feeding hay and grain. Sheep can feed from either side. Note construction for keeping chaff, etc., out of fleeces.

has been found dead on her back because of the neglected "dead" furrow.

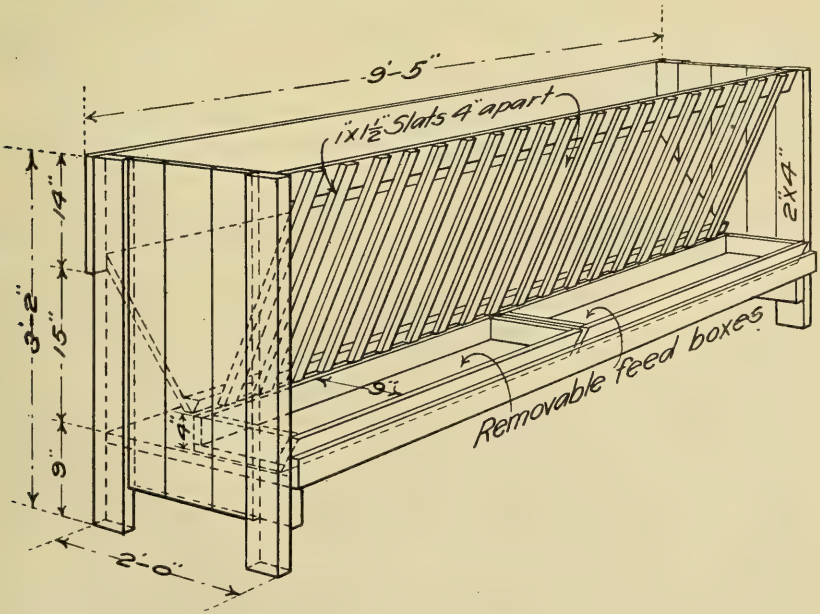

FIG. 12.—Combination rack for feeding hay and grain. Rack is so constructed that the grain troughs may be pulled back and feed put in them without entering the pen.

For permanent pastures blue grass, white clover, timothy, orchard grass, Bermuda grass, meadow fescue, and redtop are used. Blue

grass has been the basis of most of the permanent pastures, and it is undoubtedly the best pasture grass. Very often a mixture of several grasses proves quite satisfactory. The different clovers have been used for sheep pastures with success, but care should be exercised in their use, especially if they have been frosted. Alfalfa is also used and it is gradually gaining in popularity, but there are several precautions to be observed in its use. Bloating must be guarded against, and sometimes this is almost impossible. Sheep that have been successfully feeding upon alfalfa fields for weeks will suddenly be affected. No plausible reason can be given for this.

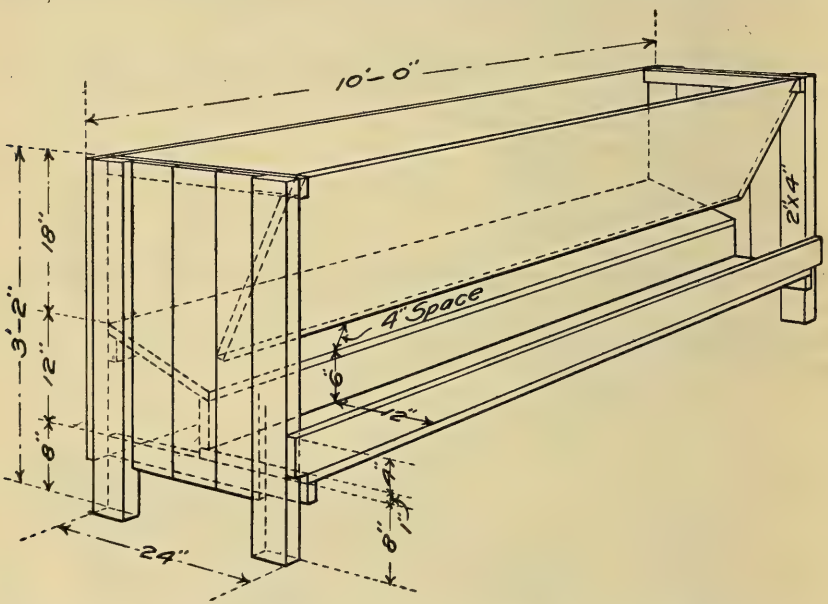

FIG. 13.—Combination rack for feeding hay and grain. Note construction for keeping chaff, etc., out of fleece.

The loss from bloat can be cut down to a minimum by careful management. It is generally agreed that having the sheep well filled up with their regular ration and watered before turning in will lessen the danger. Another precaution is to allow the sheep freedom upon the field. It is considered injurious to drive or hurry them.

Annual pastures are used in America more to supplement permanent pastures and to flush and fatten sheep than as a complete pasturage system. However, Shaw of Minnesota[1] maintained sheep throughout the season on annual pastures with fairly good results. A number of crops are used for annual pasturage, the most widely known of which are rape, oats and peas, rye, cowpeas, soy beans, barley, kale, and wheat.

[1] Agricultural Experiment Station of the University of Minnesota, Bulletin 78, St. Paul, 1903.

Rape.—Rape is one of the most popular of the annual pastures. It is largely used for pasture for lambs at weaning time and for flushing the ewes. There is more or less danger from bloat, however, and it is recommended that the sheep be given a full feed of their regular ration before being turned into the field. One reason for its wide popularity is that it can be sown after some early maturing crop has already been harvested, since it takes it but from 8 to 10 weeks to be ready for use.

Field peas.—Field peas are commonly used for fattening sheep in some parts of the West. The San Luis Valley in Colorado is especially noted for its pea-fattened lambs. The gains with field peas are very economical.

Oats and peas.—Oats and peas sown together make excellent forage, and several crops of these can be raised if the time of planting between successive crops is about two weeks.

Rye.—Rye is commonly used for fall and winter pasture, and it is also used in the spring until the joints appear. Its use is probably more widespread than that of any of the other annual pastures.

Vetches.—Vetches are usually sown with some other crop, such as oats, rye, peas, or rape, and have proved a valuable pasture in some sections, especially in the South.

Cowpeas and soy beans.—These have been used less for pasture than for hay.

Barley.—Barley is used to a limited extent for sheep pasture in the South.

Kale.—Kale makes an excellent pasture of somewhat the same nature as rape. It is not commonly used in this country except in the Willamette Valley, where the famous long-wooled sheep of this region feed upon it.

Wheat.—Many farmers allow their sheep to pasture upon their wheat fields for a short time in the spring, especially if the wheat is making too rapid growth.

FEEDING ROOTS.

Roots are to sheep in winter what pasture is in summer. In late years silage has been substituted for them to a certain extent, but, nevertheless, they still maintain a wide popularity. Breeding ewes, especially, thrive upon this form of succulence, roots going a long way toward producing a strong, healthy lamb crop. All classes of sheep are prevented from becoming constipated and kept in healthy condition by their use. The dry matter of roots has no special advantage over that of grain, but on account of their wholesome effect in toning up the system they are invaluable in feeding sheep.

Roots should be pulped or cut into small pieces for feeding. A root cutter is almost indispensable where many roots are fed. Up to 10 pounds per sheep per day have been fed, depending upon the

class of sheep, but this is a rather heavy ration. The amount of roots may also vary with the available supply and the amounts and kinds of other feeds in the ration. During pregnancy the ewes of the Government flock of Southdowns at Middlebury, Vt., receive 2 pounds of turnips per day, and excellent results have been obtained.

Turnips, swedes, and rutabagas are the best roots for all classes of sheep. Sugar beets and mangel-wurzels should not be fed to rams or wethers under any conditions, because of their bad effect on the kidneys and bladder, and should not be fed to ewes that are far advanced in pregnancy, as it is believed that their use may cause abortion.

SILAGE.

Silage of good quality has been fed to all classes of sheep with success. The use of this succulence for sheep has attracted the attention of most farmers only during the past few years, but some breeders fed it years ago with good results. A great deal has been said of its bad effects upon sheep, but these have arisen because a poor quality of silage (acid, frozen, or moldy) has been fed. This succulence is supplanting roots to a considerable extent because of its cheaper cost of production. Three to 4 pounds per day is as much as should usually be fed, though there are trials reported where as much as 5 pounds have been successfully given.

The Purdue Experiment Station[1] reports, after three years of experimenting, that silage is an extremely palatable food and a desirable form of succulence for breeding ewes and lambs. The pregnant ewes receiving silage made larger gains than those receiving a similar ration without it. Ewes with fall lambs also made larger gains when fed silage. The gain with fall lambs was in favor of the silage-fed lot. From 2 to 4½ pounds were fed to pregnant ewes.

Clover silage has proved a very satisfactory feed, but the cost of making and the difficulty of keeping were against it. Pea silage has also been fed to a limited extent. Ensiled beet leaves have been fed in Germany, but they are not very nutritious. Emphasis must be placed upon the importance of using silage of good quality, as the use of a frozen, acid, or moldy product has often resulted fatally.

CABBAGE.

Cabbage is largely used for feeding show sheep. Sheep like it very much, eating it when they refuse all other feed, and it has a good effect upon them. From 2 to 3 pounds per day give good results. The cost of production is too high for it to be used for commercial feeding. Another objection to its use is that its keeping qualities are poor.

[1] Agricultural Experiment Station of Indiana, Bulletin 147, La Fayette, 1910.

PUMPKINS.

Pumpkins are a very satisfactory stock food and are readily eaten by sheep. Their keeping qualities, however, are such that they can be fed only through the fall and early winter. They should be cut into small pieces and fed in about the same quantities as roots. A crop of pumpkins can often be grown in the cornfield, and their feeding value and the variety they add to the ration amply repay the extra cost.

SOILING CROPS.

Little work has been done on soiling market sheep. Daintiness on the part of the sheep in refusing to eat feed that is in any way unclean, the variety desired by the sheep, and the extra amount of labor necessary preclude this practice. Henry, at the Wisconsin Experiment Station[1] soiled a lot of sheep on green-corn fodder and clover, and produced gains at a reasonable cost, but it is hardly possible that soiling will ever be important in commercial flock husbandry because of the difficulties mentioned. Show sheep are more often soiled, as more time and attention can be devoted to them.

CONCENTRATES.

Although sheep are eminently adapted to digesting large amounts of roughage, they also can use grain to good advantage and under many conditions give the best results only when they receive it.

Corn.—Corn has been fed more to fattening sheep in this country than any other grain. The ears are sometimes chopped and fed in this way. More often it is fed shelled, cracked, or ground into meal. Corn-and-cob meal is also used. The value of the cob lies in the fact that it lightens the ration. It should be ground fine or the cob will not be eaten. While corn is an excellent grain for fattening stock, it is suitable only in small amounts for breeding and young stock. It is too carbonaceous in character to form more than a small part of their ration.

Barley.—Barley is widely used in fattening sheep outside of the corn belt. In the West and Northwest it has gained its widest popularity, and the results from its use have been quite favorable as compared with corn.

Oats.—Oats are an excellent grain for growing sheep or for breeding stock, especially when fed in connection with other grains. When fed alone for fattening purposes oats are not generally as satisfactory as corn or barley. However, some western trials report very satisfactory results.

Wheat.—Because of the continued high price of wheat it is of little importance as a feed for sheep. Damaged wheat and screenings are fed to sheep, but not to as great an extent as formerly.

[1] Agricultural Experiment Station of the University of Wisconsin, Eighth Annual Report (1891), Madison, 1892.

Spelt.—Spelt, or emmer, is a rather inferior grain for sheep. In most of the feeding trials in this country where spelt was fed it was at or very near the bottom of the list.

Peas.—Cracked peas and pea meal are highly nitrogenous feeds; they have given their best results when fed with other grains.

Cotton seed, cottonseed meal, cake, and hulls.—Whole cotton seed is fed to sheep to a certain extent in the South. About one-fourth of a pound per head is usually given. Ground cotton seed has also been fed. Cottonseed meal is the most important of these feeds. It is rarely fed alone. In the South the meal is mixed with the hulls and is considered a very satisfactory feed. One pound of meal to 4 or 5 pounds of hulls is the ordinary proportion. The cake is also largely fed, and it is a very convenient form. The use of these feeds outside of the South is to supplement rations low in protein; consequently, they are usually fed in small amounts. In fact, it is inadvisable to feed large amounts, as these feeds are very dense and concentrated.

Flax, linseed cake and meal.—Flax is sometimes sown with oats, the flaxseed and oats being fed together after being thrashed. Ground flaxseed has also been fed to sheep with good results, but it is too expensive to become widely used. Pea or nut sized linseed cake is more desirable than the meal for sheep, as it is more easily masticated. These feeds are high in protein and are largely used for the same purpose as the cottonseed products, but they do not have the undesirable features of these latter products.

Gluten meal and gluten feed.—Both gluten meal and feed have been fed with good results. The meal is a very concentrated feed of much the same nature as linseed meal. Gluten feed can be used to good advantage in combination with oats, bran, etc., and when thus fed makes an excellent ration for ewes suckling lambs.

Bran.—Bran is a superior concentrate for sheep when fed in connection with the various grains and usually constitutes from one-fourth to one-half of the mixture. It is especially good for breeding ewes or growing stock, being more muscle than fat building in character, and it also has a good effect upon the digestive system, acting as a laxative and toning up the sheep. It also forms an excellent medium for holding together the other concentrates of the ration.

Beans.—Beans are reported by the Rothamsted station in England as being undesirable for sheep, but good results have been obtained from their use in this country. They are either cracked or fed as bean meal. Generally beans are too high in price to be fed, but damaged or discolored ones, when available, can often be profitably fed. A small quantity of ground beans has been successfully used in the ration of show sheep.

GRAIN TROUGHS.

A number of different kinds of grain troughs have been advocated for feeding the grain ration. The V-shaped trough is a very common type but is not very desirable, as too much grain is thrown out and wasted by its use. The flat-bottomed trough is much superior in

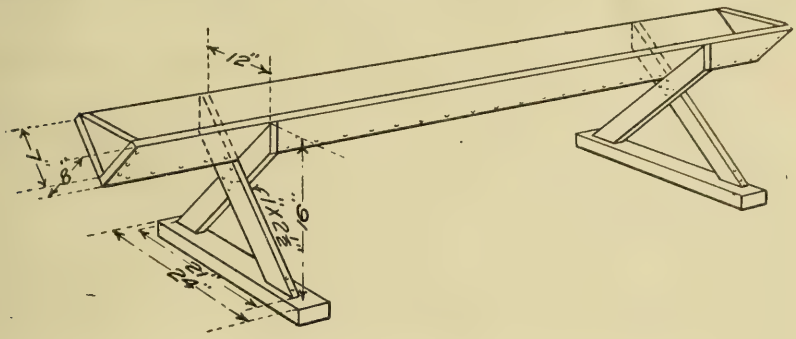

FIG. 14.—V-shaped grain trough. This type is extensively used, but is objectionable on account of the large amount of feed that is thrown out and wasted.

this respect, and it is also the best type for feeding roots. Two troughs (bottoms together) are sometimes mounted upon pivots, forming a reversible trough. They are cleaned out by revolving, the one being inverted while the other is in use. They are especially

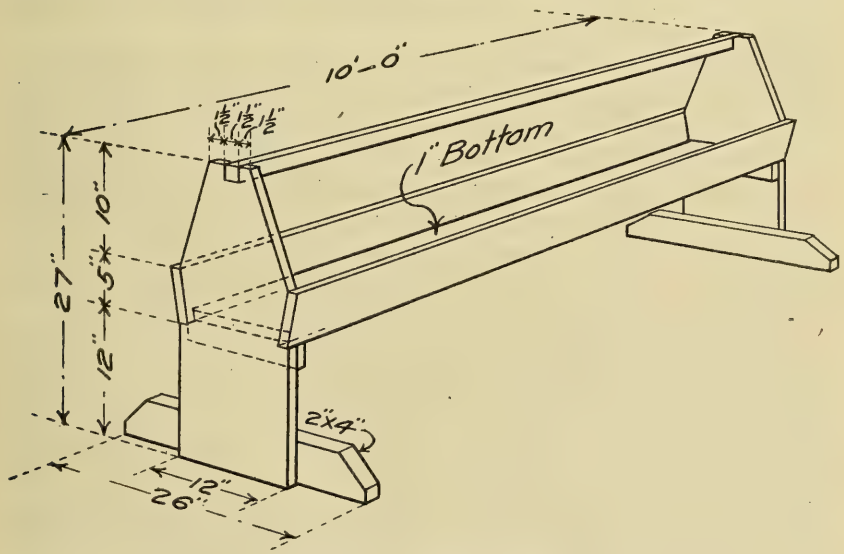

FIG. 15.—Excellent type of trough for feeding grain and roots.

desirable for feeding grain outdoors. The combination trough and rack has already been described on page 38. The V-shaped and flat-bottomed troughs are illustrated in figures 14 and 15 and Plate IV, figure 2.

MISCELLANEOUS FEEDS.

Potatoes.—Potatoes are ordinarily too valuable to be fed profitably to sheep. Heavy yields have occasionally in past years lowered the market price to such an extent that it did not pay to market them. On such occasions potatoes are an economical feed for sheep. They should be cut up in small pieces like roots. Small potatoes can also frequently be fed to sheep with profit.

Molasses.—Molasses has been fed to sheep with more or less success. It can be fed either with the grain or roughage.

Sugar.—Low-grade sugar is sometimes fed to sheep. It is sometimes sprinkled upon the lambs' ration to induce them to eat.

Wet and dry beet pulp.—Wet beet pulp can profitably be fed to fattening sheep, if the source of supply is near at hand. It can form a considerable portion of the ration during the first part of the fattening period, as much as 12 to 15 pounds having been fed, but during the latter part it should be fed only in small amounts to act principally as an appetizer. If largely fed at this time it is said to produce soft flesh.

Dried beet pulp has, in some cases, produced larger gains than the wet. It can be used for feeding over a much larger area, because of its reduced weight and better keeping qualities.

Meat meal.—This product of the slaughterhouse has been fed to sheep to a limited extent. Dried blood has also been fed to young lambs with reported success.

Water.—The flock should constantly have access to an abundant supply of clear, pure water, both while in the barn and in the pasture. It has been stated that the dew on the grass furnishes enough water, but such is not the case. It is true that sheep can exist upon dews and snows for a long time, but to expect them to thrive under these conditions is certain to prove disappointing. A sheep needs from 1 to 6 quarts of water per day, depending upon the nature of the ration, climate, size of sheep, etc. They should never be forced to drink dirty or stagnant water because of the danger of contracting disease.

Salt.—Either too much or too little salt can be fed to sheep. It is sometimes claimed that an overdose of salt will cause abortion in pregnant ewes. The veracity of this statement has never been proved, but it is a wise precaution to avoid an excess, especially if the flock has had none for a long time.

By having a constant supply available the sheep can help themselves whenever they desire, and there is no danger of their consuming too much. Rock salt is a convenient form for this purpose, especially when fed outside. If granular salt is used in the winter time, a little sulphur and pulverized copperas mixed with it acts as a tonic and improves the health of the flock. These can be mixed by the flockmaster himself and take the place of the "so-called" medicated salts.

SHEARING AND CARE OF THE WOOL.

Flocks are shorn in some parts of the United States during almost every month of the year. From Texas to Montana there is a range of six months in the time of shearing. In Texas and California the flocks are shorn twice a year, spring and fall. By this practice it is claimed a pound more of wool per sheep is obtained. However, the staple is not so valuable because of its shorter length.

Most farm flocks are shorn during April and May. The time of shearing will vary with the locality, season, shelter available, etc. Shearing should not take place too early or the sheep will suffer from the cold, and it should not be delayed too long or they will be affected by the heat. In the latter case they lose flesh and shed their wool.

The Michigan station[1] found that early shearing (during April) gave heavier average fleeces with greater strength of fiber. Where early shearing is practiced, suitable shelter should be provided until the sheep become accustomed to the change. As mentioned under "Shearing breeding ewes," the flock should be shorn before being turned out to pasture.

In former years it was common to wash sheep before shearing, but this is seldom practiced at the present time. Sheep should never be shorn when the fleece is damp. There is danger of deterioration in quality when damp wool is stored.

MACHINE COMPARED WITH HAND SHEARING.

Machine shearing is gradually taking the place of hand shearing, especially in the larger flocks. One can learn to shear much faster, the work is easier, more sheep can be shorn in a day, more wool secured, and a smoother and neater job can be done with a machine. The sheep are not cut so often nor so severely, and "second cuts" of the wool are not so frequent as with hand shears. However, shearing with a machine is objectionable either early or late in the season because the wool is shorn so closely.

A clean place should be provided for shearing. Every possible precaution should be taken to keep all foreign material out of the wool. If a smooth, clean floor is not available, a temporary platform should be built. In shearing by hand many shearers prefer to use a bench about 18 inches high. The principal objection to this is that it is necessary to lift the sheep upon it. The sheep should be confined near the place of shearing to lessen the amount of work in handling them.

With the ordinary farm flock a hand machine is commonly used, but power machines are advisable where the size of the flock will warrant it. A sufficient number of combs and cutters should be kept on hand to cover breakage and prevent delay in shearing.

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[1] Experiment Station of the Michigan Agricultural College, Bulletin 178, East Lansing, 1900.

METHOD OF SHEARING.

While it is impractical to tell exactly how to shear a sheep, there being several methods of procedure, the following precautions are worthy of mention.

The sheep should be handled humanely and held so that they will struggle as little as possible. The skin should be kept stretched beneath the shears, so as to avoid unnecessary cutting. Special care should be taken in shearing the ewes about the udder and the ram about the sheath.

The shears should be kept close to the body of the sheep and not allowed to run off at a tangent, as this makes necessary a second cutting of the wool. The fleece should not be broken, but kept entire throughout the operation. After removing, it should be spread out in a clean place, cut side down, and as much as possible of the foreign material thrown out. The tags should be separated from the remainder of the fleece and placed by themselves. Loose parts of the fleece should be placed in the center, ragged edges turned in, then the fleece should be rolled up, cut side out, and tied with appropriate twine. It should not be rolled too tightly, and too much twine should not be used. Once around the fleece each way is sufficient. Wool boxes should not be used for tying. Their use makes attractive fleeces, but the wool is tied up too tightly and wool buyers discriminate against it in this condition. It is important that the right kind of twine be used. A light, smooth, hard twine should be used that will not become entangled in the fleece, and thus leave fibers in the wool. Sisal is very objectionable from this standpoint. The fiber from this twine gets into the wool and is woven into the cloth. It will not take the dye, and consequently it must be picked out by hand. The use of sisal has caused a loss of thousands of dollars, and many buyers refuse to purchase wool that has been tied with this twine. Others cut the price from 4 to 5 cents per pound for its use. Much wool twine, which is objectionable in no other way, is much coarser than is necessary. Linen or paper twines are excellent for tying, the objection to paper twine being that it is stiff and difficult to knot. A string from 7 to 8 feet long is sufficient for tying an ordinary fleece.

WOOL SACKS.

The use of better wool sacks is one way in which the condition of the domestic clip can be improved. Australia is much more progressive in this respect. The sacks used there are smooth, free from fiber, and occasionally lined with paper. On the other hand, American wool comes to the market in the cheapest possible sacks, and frequently they are not even shaken out before being filled. Many sacks come to market containing only about half as many fleeces as

they are capable of holding. By packing down the fleeces the expense for sacks can be cut down considerably, and they will handle all the better. From 30 to 40 fleeces can be placed in a sack, if well packed.

STORING WOOL.

It is a rather infrequent practice to store wool upon the farm, as it is usually sold soon after shearing. When stored, a clean, dry, vermin-proof place should be selected. A piano box is a very suitable receptacle for wool, if it is not immediately sacked. However, it is much better to sack the wool immediately after shearing, as it can be kept much cleaner.

COST OF MAINTENANCE.

The principal difficulties in computing the cost of maintenance of sheep are that they are usually kept in connection with other stock, and that oftentimes they consume feeds that would otherwise go to waste. There is also a wide range in the cost of maintenance in the different parts of the farming section, due mostly to climatic conditions. In the South, where little or no shelter is provided, and where the sheep subsist almost entirely upon pasture, the cost is very low; but where sheep must be housed and fed for several months of the year, as in New England, the other extreme is found.

The cost of maintaining sheep has been estimated at from $0.50 to more than $5 per head per year. The Tariff Board[1] reported an average cost of $2.44 for fine wool and $2.78 for cross-bred sheep in Ohio and neighboring States. The cost of maintenance in the farming section would probably average between these latter figures.

But even with the average cost given, it is impossible to calculate beforehand the profits of sheep husbandry. Those having had experience are aware of this fact. Differences in expenditures and receipts, due to management, location, fluctuation of market prices, and accidents, make the most careful calculations misleading.

While it is impossible to calculate beforehand the profits, and while it is difficult to obtain the exact cost of maintenance, it is nevertheless very important that records of receipts and expenditures, as complete as possible, be kept of the flock. These would not only indicate whether a man was making a profit or losing money, but would show the cost of keeping sheep to be made up of a number of items, several of which would probably be capable of considerable reduction. The items generally capable of reduction are labor, forage, depreciation on equipment and breeding stock, and mortality.

[1] Report of the Tariff Board, vol. 2, pt. 2.

METHODS OF REDUCING COST OF MAINTENANCE.

By having the sheep barn conveniently arranged, and by having all necessary equipment, such as hurdles, lots, and chutes, the labor cost can be reduced. It can also be lowered by having the largest flock the conditions will permit.

By growing on the farm most of the feed, especially the most expensive part of it, and by raising crops that will yield highest, the cost of feed can be lowered. Sheep farming rarely pays where a large part of the feed must be bought. Depreciation on the equipment and the flock can be controlled to a certain extent. Keeping the barns, sheds, and lots in good order lessens this item. Repairing done immediately is far less expensive than when it is delayed. The depreciation of the flock depends more or less upon the care it gets. The best management will reduce this considerably. The ordinary loss from mortality can also be reduced by the best care and management.

Interest upon the investment, taxes, and insurance are practically fixed charges. Making the investment as low as possible and securing the most favorable rates of interest and insurance are reductions that may be practiced.

It is not necessary to have expensive sheep buildings. As mentioned before, sheds can be made to serve the purpose excellently, and as good results can often be secured with them as with more pretentious structures. Quite often unoccupied portions of the barn or vacant sheds can be made ready for sheep at a small cost, thus further reducing expenses. It is well to start out with inexpensive buildings, then if the flock warrants it these can be replaced with better ones.

While it is desirable to reduce the cost of maintenance in the ways enumerated above, it does not pay to sacrifice anything essential to continued development of the flock. It is poor policy to reduce this cost at the expense of health or productivity.

CONSUMPTION OF MUTTON ON THE FARM.

MUTTON NOT FULLY APPRECIATED IN THE UNITED STATES.

Mutton never has been as highly appreciated in America as it should be. Probably one reason for this has been the supply of cheap beef that this country has enjoyed up to the past few years. The days of cheap beef are over, however, and it is necessary that some substitute for it be found. Mutton is the logical solution of the problem. It is true that the people will have to be educated more thoroughly as to its value, but mutton is now more in favor as a food than it used to be. A particular class of American people who have underrated mutton are the farmers, many of whom keep a

flock yet seldom, if ever, slaughter one for their own use. A lamb or sheep could frequently be killed for use by the flock owner and it would prove much cheaper than buying meat. There would also be the satisfaction of knowing that the meat was fresh and wholesome.

PRECAUTIONS IN SELECTING SHEEP FOR SLAUGHTERING.

Probably one reason why mutton has not been more popular on the farm is that not enough care has been exercised in selecting and slaughtering the sheep. To get the best mutton a sheep should be selected that is in good health; gaining rather than losing flesh. It should be in fairly high condition also, as this insures more tender and juicy meat. If the animal is too old the mutton will be tough and unsavory.

No feed should be given for 24 to 36 hours before killing, or the carcass will be reddish looking and unattractive and there will be more danger of the woolly taste. However, plenty of water should be given. The sheep should not be allowed to become excited or overheated, nor should it be driven a long distance immediately before slaughtering. If something of this kind has taken place, the sheep should be allowed to recover from it before being killed.

SLAUGHTERING SHEEP.

The following paragraphs upon slaughtering sheep are taken from Farmers' Bulletin 183, "Meat on the Farm: Butchering, Curing, and Keeping."

Much of the sheepy flavor of mutton comes from the generation of gases in the stomach after the sheep is killed. For this reason sheep should be dressed as rapidly as possible. A platform 6 or 8 inches high is a convenient thing to work on and aids in keeping the blood away from the body, insuring a cleaner carcass. A clean, dry place is necessary for neat work. Water or blood on the wool makes it very difficult to dress the animal nicely.

Killing.—If the sheep is an old one it may be stunned before bleeding. If a young one the same purpose is served by dislocating the neck after cutting the throat. This is accomplished by putting one hand on the poll or top of the head and the other hand under the chin, giving a sharp twist upward. Lay the sheep on its side on the platform, with its head hanging over the end. Grasp the chin in the left hand and stick a knife through the neck just back of the jaw. The cutting edge of the knife should be turned toward the spinal column and the flesh cut to the bone. In this way it is possible to avoid cutting the windpipe.

Skinning.—Split the skin over the back of the front legs from the dew claws to a little above the knees. Open the skin over the windpipe from brisket to chin, starting it slightly on the sides of the neck. Split the skin over the back of the hind legs to the middle line and skin the buttock. The skin should also be raised over the cod and flanks. Skin around the hocks and down to the hoofs, cutting off the hind feet at the toe joints. Run the knife between the cords and bone on the back of the shins, and tie the legs together just above the pastern joints. No attempt should be made to skin the legs above the hock until after the carcass is hung up. Hang the sheep up by the hind legs and split the skin over the middle line. Start at the brisket to "fist off" the skin. This is done by grasping the edge of the pelt firmly in one hand, pulling

it up tight and working the other with fist closed between the pelt and the body. The "fisting off" should be downward over the fore quarters and upward and backward over the hind quarters and legs. It is unwise to pull down on the skin over the hind legs, as the membrane covering the flesh is sure to be ruptured and an unsightly appearance given to the carcass. The wool should always be held away from the flesh for the sake of cleanliness. The skin on the legs should be pulled away from the body rather than toward it, in order to preserve the covering of the meat. When the pelt has been loosened over the sides and back it should be stripped down over the neck and cut off close to the ears. The head may then be removed without being skinned by cutting through the atlas joint.

Gutting.—Begin removing the entrails by cutting around the rectum and allowing them to drop down inside. Do not split the pelvis. Open down the belly line from the cod to the breastbone and take out the paunch and intestines, leaving the liver attached to the diaphragm. If the mutton is for home use, split the breastbone and remove the heart, lungs, and diaphragm together. For marketing it is best not to split the breast. Reach up into the pelvis and pull out the bladder. Wipe all blood and dirt from the carcass with a coarse cloth wrung nearly dry from hot water. Double up the front legs and slip the little cord, found by cutting into the fleshy part of the forearm, over the ankle joints.

CARE OF THE MEAT.

After dressing, the carcass should be cooled to 40°, or as near that as possible. In the summer it will be necessary to have ice for this purpose. Where there is a farm refrigerator the carcass can be placed in it, provided there is a circulation of dry air and no objectionable odors are present. Mutton can be kept for a week or ten days under these conditions. In the majority of cases, however, ice is not available on the farm. Under these conditions the sheep or lamb, as the case may be, should be slaughtered in the evening, the carcass allowed to hang out overnight (where nothing will disturb it), and taken to a cool dry room or cellar in the morning, before the flies are about. If the carcass is split it will cool out more rapidly. Under these conditions it is a good plan for two or more farmers to club together, each taking a part of the carcass, so that there will be no danger of the meat spoiling before it can be used.

In the winter there is little difficulty about keeping the meat. A good way to keep mutton at this time is to allow it to freeze up and to cut off enough for use from time to time with a saw. A single freezing does not injure the quality, but alternate freezing and thawing is harmful and should be avoided.

Lamb and mutton should never be used for food until it is thoroughly cooled out. Lamb is as good as it ever will be as soon as it is thoroughly cooled, but mutton improves with ripening for a week at 40° to 45° F. Mutton can be corned, but it is not as palatable nor is it as nutritious as the fresh meat. The hams are sometimes spiced and are considered by many to be a delicacy when prepared in this way.

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THE COMMERCIAL FATTENING OF POULTRY.

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INTRODUCTION.

The fattening experiments described in Bureau of Animal Industry Bulletin 140, entitled "Fattening Poultry," are continued in this bulletin, which represents the results of two more years' work covering the feeding seasons of 1911 and 1912. The methods and equipment at the four feeding stations are the same as described in the former bulletin, except for slight changes in equipment which are noted in this publication. The present experiments cover wider conditions and include larger numbers of birds than the previous work, and so permit of much better comparisons being made. The rations were varied at some of the stations, thus giving good comparisons of the value of different feeds under the same conditions; while the differences in equipment, methods, and rations at the various stations allow comparisons of results secured in several different ways.

The extent of the experiments, the numbers of birds included in each test, and the opportunity for comparison with the previous season's work eliminate largely the possibility of error that is liable to occur in dealing with small numbers, which give very variable results in fattening tests. The danger of deriving wrong conclusions by not properly allowing for the influencing conditions is also reduced to a minimum.

THE FEEDING EXPERIMENTS.

A full description of the four stations where the feeding was carried on will be found in Bulletin 140, before mentioned, as well as a number of other details concerning the equipment and methods of fattening in the large poultry packing houses of the Middle West which are not included in the present paper, as it is considered unnecessary to repeat them here.

The work of 1911 and 1912, herein described, is composed of four experiments, designated A, B, C, and D. These are summarized and

discussed in the following pages, and the complete details of each are recorded in Tables I to IV of the appendix at the end of the paper. The main object of the summary tables is to show the results according to length of feeding period, which varied from 6 to 21 days in Experiments A and D, from 9 to 18 days in Experiment B, and from 7 to 16 days in Experiment C. All the various kinds of birds are necessarily mixed together in showing these results, but the averages for two of the main classes—broilers and roasters—are shown separately, irrespective of length of feeding period, at the bottom of each table.

The actual cost of producing the gains in each case is given under each experiment, and as the price of grain and milk varied somewhat in the different localities, the relative amount of feed required to produce a pound of gain is used in comparing the efficiency of the rations and the methods at the different stations rather than the cost of the gains, except where different feeds are used.

PRICES OF THE FEED USED.

Before describing the feeding operations, the following list of average prices of the grain and buttermilk used is given:

TABLE 1.—*Average prices of grain and buttermilk used in the feeding experiments.*

Year.	Feed.	Experiment A.	Experiment B.	Experiment C.	Experiment D.
1911	Corn meal, per 100 pounds	$1.38	$1.32	$1.45	$1.35
1912	do	1.48	1.39	1.69	1.74
1911	Low-grade wheat flour, per 100 pounds	1.42	1.30	1.35	1.30
1912	do	1.50	1.38	1.45	1.52
1911	Oat flour, per 100 pounds		2.25		
1912	do		1.50		
1911	Shorts, per 100 pounds	1.25	1.30	1.28	1.30
1912	do	1.20	1.18	1.27	1.20
1911	Linseed meal, per 100 pounds			2.50	2.50
1911	Tallow, per 100 pounds		7.00		
1912	do		8.00		
1911	Buttermilk, per gallon		.02	.01	
1912	do		.02	.01	
1911	Condensed buttermilk, per gallon	.08		.08	.08
1912	do	.06			.08
1912	Graham flour, per 100 pounds				1.50
1912	Bone, per 100 pounds				3.25
1912	Meat, per 100 pounds	2.00		2.50	

EXPERIMENT A, 1911.

Most of the lots in this experiment at Station 3 were fed for a short time only during the first part of the feeding season, due to the lack of suitable equipment and space for fattening. The station was overcrowded twice during the season, which lowered the gains and increased the cost in both instances. The low, tin roof made the building too hot during warm weather, and produced a thick condensation of moisture on the inside of the roof in cool weather, when the building was partially closed. The gains, except for these two crowded periods, were fairly consistent throughout the season and

compare favorably with the results at the other stations. The cheapest gains were made on short-fed lots, but many of the lots could have been fed longer with profit if conditions had been good for fattening.

FEED.

A ration made up of equal parts, by weight, of corn meal and low-grade wheat flour was fed from the commencement of the season, July 23, until August 11, when shorts were added, making equal parts of corn meal, flour, and shorts up to September 7, at which time the ration was changed to 3 parts corn meal and 2 parts flour, which was fed to the end of the season. All of these rations were mixed with condensed buttermilk, diluted with one part of water, making a thick feed. It may here be stated that whenever "parts" are mentioned in connection with a ration, it means parts by weight, and "flour" always means low-grade wheat flour.

Each of the above rations produced good results, and no apparent change in gains occurred which could be attributed to the feed when the ration was changed. The heat at this station was at times very intense, which may have made the ration containing shorts preferable to the regular ration of 3 parts of corn meal and 2 parts of flour, but the results compared with those at Station 2 (Experiment D) do not indicate that there was any advantage in adding a large proportion of shorts to this feed, provided thick condensed buttermilk was used. Later in the season good results were secured on a ration of 3 parts of corn meal and 2 parts of low-grade flour without any shorts.

In this experiment the average cost of producing flesh was greater with broilers than with roasters, which was due to the unfavorable conditions in the house, particularly to the extreme heat in the first part of the season and to overcrowding later.

TABLE 2.—*Summary of Experiment A, 1911, Station 3, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
2,096	6	3.04	18.0	8.0	12.4	4.64	2.17	3.31
13,587	7	3.12	16.0	9.0	12.6	4.72	2.70	3.47
6,063	8	2.71	19.0	10.0	11.8	4.90	2.75	3.61
12,925	9	2.38	30.0	14.0	19.3	4.55	2.29	3.20
11,160	10	2.23	27.0	10.0	21.0	5.66	2.91	3.49
7,030	11	1.86	33.0	20.0	24.5	4.14	2.67	3.71
3,040	12	2.39	19.0	17.0	17.8	5.22	4.77	4.91
1,280	13	2.15	26.0	21.0	23.5	4.75	3.61	4.18
1,372	14	1.58	45.0	25.0	33.2	6.64	3.64	5.20
610	16	1.62	43.0	31.0	37.3	5.53	4.62	5.05
501	15	1.7	.....	.....	41.0	.....	.....	3.93
480	17	1.5	.....	.....	40.0	.....	.....	5.17
60,144	.....	2.47	.....	.....	18.6	.....	.....	3.62
10,153 broilers	.....	1.58	.....	.....	26.9	.....	.....	3.91
22,256 roasters	.....	3.15	.....	.....	13.5	.....	.....	3.56

TABLE 2.—*Summary of Experiment A, 1911, Section 3, arranged according to length of feeding period*—Continued.

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
2,096	10.96	3.82	7.38	1.72	0.77	1.18	12.68	4.59	8.56
13,587	10.93	6.24	7.99	1.53	.82	1.13	12.46	7.23	9.12
6,063	11.23	5.40	8.19	2.18	.91	1.41	12.73	6.46	9.60
12,925	9.29	5.49	7.00	2.60	.77	1.29	11.23	6.27	8.29
11,160	15.01	5.66	7.31	3.65	1.02	1.46	16.66	6.76	8.77
7,030	8.15	5.68	7.41	2.01	1.10	1.44	10.16	6.78	8.85
3,040	9.45	8.70	9.02	1.62	1.49	1.56	11.07	10.19	10.58
1,280	8.83	7.14	7.99	1.60	1.39	1.49	10.43	8.53	9.49
1,372	15.50	8.48	12.17	2.11	1.33	1.71	17.61	9.81	13.88
610	12.87	12.40	12.65	1.84	1.63	1.73	14.71	14.03	14.38
501	.....	.....	8.66	.....	.....	1.38	.....	.....	10.04
480	.....	.....	12.13	.....	.....	1.80	.....	.....	13.93
60,144	.....	.....	7.83	.....	.....	1.35	.....	.....	9.18
10,153 broilers	.....	.....	8.42	.....	.....	1.52	.....	.....	9.94
22,256 roasters	.....	.....	8.34	.....	.....	1.19	.....	.....	9.53

EXPERIMENT A, 1912.

The ration at Station 3 in 1912 was 3 parts of corn meal and 2 parts of low-grade wheat flour throughout the season, with 25 per cent of shorts added from August 21 to September 8 and with about 6 per cent of mixed feed added during September and November. The shorts and mixed feed gave fair results in warm weather, but no advantage was found when feeding them in cool weather. The specially prepared mixed feeds used in September cost $2.70 per 100 pounds and were too expensive, but a mixed feed used later in the season cost only $1.60 per 100 pounds, which compares favorably in price with the other feeds. However, it would probably be advisable to substitute shorts for mixed feeds, as the latter are more apt to be adulterated. Lot 2 was fed 10 per cent of meat in addition to the regular ration, while lot 45 was fed a specially prepared mixture to note the effect of these feeds on feather picking, but no consistent results were obtained in these experiments. This subject is discussed in detail under the heading "Feather picking."

Condensed buttermilk, diluted with water and mixed with grain—13.5 gallons to 100 pounds—was fed throughout the season. This proportion of condensed buttermilk, while increasing the cost of the feeding, gave profitable results, as the general conditions at this station were not conducive to good results in fattening. The proportion of condensed milk to grain was double that used in Experiment C. The broilers and roasters were separated at this station and fed for different lengths of time. The results secured during November were very poor, there being an increased cost of gain compared with 1911.

TABLE 3.—*Summary of Experiment A, 1912, Station 3, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
748	6	3.60	.....	.....	6.0	.....	.....	5.40
5,456	7	3.13	17.0	4.0	11.6	10.53	2.98	4.88
5,640	8	3.14	16.0	5.0	7.70	8.35	3.44	6.85
22,656	9	2.59	23.0	5.0	14.4	9.04	2.84	5.22
18,240	10	2.48	28.0	8.0	18.7	6.67	2.65	3.92
18,480	11	2.26	41.0	6.0	20.4	9.96	2.75	3.87
10,880	12	1.99	40.0	13.0	26.0	4.02	3.11	3.51
4,160	13	1.89	31.0	21.0	26.9	4.46	2.75	3.49
3,200	14	1.88	37.0	30.0	33.6	4.69	2.98	3.64
288	15	1.63	.....	.....	3.0	.....	.....	5.07
321	21	2.26	.....	.....	35.0	.....	.....	4.27
90,069	.....	2.44	.....	.....	18.6	.....	.....	4.42
10,852 broilers	.....	1.69	.....	.....	25.7	.....	.....	3.80
23,490 roasters	.....	3.24	.....	.....	9.2	.....	.....	6.83

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
748	.....	.....	9.60	.....	.....	1.91	.....	.....	11.51
5,456	19.35	5.42	9.13	4.02	1.06	1.79	23.37	6.55	10.92
5,640	15.77	6.63	12.87	3.11	1.15	2.44	18.88	7.78	15.31
22,656	17.46	5.48	9.81	3.43	.95	1.82	20.89	6.40	11.63
18,240	12.94	5.09	7.67	2.13	.84	1.31	15.07	6.11	8.98
18,480	19.29	5.56	8.78	3.78	.92	1.70	23.07	6.48	10.48
10,880	8.14	6.39	7.01	1.70	1.11	1.43	9.67	7.55	8.44
4,160	8.84	5.67	6.93	1.59	1.17	1.43	10.37	6.84	8.36
3,200	9.01	6.06	7.22	1.52	1.09	1.27	10.53	7.30	8.49
288	.....	.....	9.37	.....	.....	1.82	.....	.....	11.19
321	.....	.....	8.51	.....	.....	1.39	.....	.....	9.90
90,069	.....	.....	8.74	.....	.....	1.63	.....	.....	10.37
10,852 broilers	.....	.....	7.37	.....	.....	1.60	.....	.....	8.97
23,490 roasters	.....	.....	12.85	.....	.....	2.42	.....	.....	15.27

EXPERIMENT B, 1911.

The total number of chickens fed in this experiment at Station 1 was 102,684, the birds being divided into 113 lots, most of which were on feed from 12 to 16 days. The results secured were very satisfactory, the lots doing especially well until the month of October, when there was a marked falling off in gains. The feeding period was about 14 days until the gains fell off, when the period was shortened because the 14-day feeding was unprofitable, while the birds made as high or higher gains during a shorter feeding period. The "roasters" and "broilers" were not separated at this station, and all of the lots were classed as "springs" except a few in July when the average weight of the birds was under 1.8 pounds.

The equipment, management, and method of feeding at Station 1 are described in Bulletin 140. The ration was varied during the summer season in the following way:

FEED.

Lots 1 to 13 received a ration averaging 1 part shorts, 2 of low-grade flour, and 2.5 corn meal, but these proportions were varied somewhat. Lots 1 to 3 did not receive any tallow. In all the rest of the lots 6 per cent of the dry feed was tallow, although lots 4 to 17 did not receive tallow during their entire feeding period. The feed for all the lots was mixed in one tank at the same time.

Tallow increased the cost of gains considerably, but did not increase the gains in proportion to the extra cost. The tallow apparently increases the gains slightly and makes the fat appear more distinctly on the birds. Many buyers judge the condition of the birds partly by the prominence of this fat, so that it may be wise to feed a small proportion of tallow in some cases. Tallow was not fed at any of the other stations included in these records. These other companies had built up a reputation for such good poultry that they were able to sell their products as high, if not higher, than those produced by the company using tallow. On the whole there does not appear to be any advantage in feeding tallow at present prices except as it affects the appearance and the sale of the product, which depends both on the market and the reputation of the producer.

OAT FLOUR.

Lots 14 to 30 received 1 part of shorts, 1 of low-grade flour, and 1.5 parts of corn meal, with 6 per cent tallow. Lots 30 to 43 received equal parts of oat flour, low-grade wheat flour, and corn meal, which proved to be a very efficient ration, producing gains with slightly less feed but at a higher cost, because of the difference between the price of oats and of low-grade flour or shorts. Oats are one of the best fattening feeds and produce very good gains, but they do not equal low-grade wheat flour at the present price of grains. Oats which were ground and reground without removing the hulls were tried on a small scale toward the end of the feeding season with satisfactory results. Both hens and large chickens ate oats thus prepared without any ill effects, and made gains. It is possible that the hulls might injure young, tender chickens, but this can only be proved by feeding. If a feeder can procure reground oats containing hulls at a price not much greater than that of low-grade wheat flour they are one of the best feeds, as they produce a good quality of flesh and can be used efficiently in fattening poultry. A ration composed of one-fourth oats, one-fourth low-grade flour, and one-half corn meal would give very good results during the first part of the feeding season, and the proportion of corn meal could be gradually increased later in the season during cool or cold weather.

BEEF SCRAP.

Lots 44 to 70 received 1 part of shorts, 2 of low-grade flour, and 3.5 of corn meal, with 6 per cent of tallow. Lots 71 to 100 received 1 part of shorts, 3 of low-grade flour, and 10 of corn meal, with 6 per cent of tallow. Lots 101 to 113 received 1 part of shorts, 1 of low-grade flour, and 2 of corn meal, with 6 per cent of tallow. Lots 92, 94, and 95 received two-thirds of a pound of good quality dried meat scraps per 100 head, which amount of meat did not seem to affect either the gain or the cost of gain. The birds ate the feed well, but not any better than the lots which did not receive beef scrap.

There does not appear to be any advantage in adding beef scrap to the regular ration if it contains plenty of milk. Beef scrap would probably be economical in a ration without milk, or where only a small amount of milk was available. Fresh meat was added to the fattening rations at several other packing houses in this State. In these cases the poultry houses were a part of a meat-packing establishment, so that a supply of the best quality of meat was regularly available for feeding. Very good results were secured in feeding this meat in a ration containing 60 per cent of steel-cut oats, 40 per cent of corn meal, with about 7 per cent of tallow added.

TABLE 4.—*Summary of Experiment B, 1911, Station 1, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
1,350	10	3.50	.....	.....	9.0	.....	.....	4.63
1,800	11	3.40	17.0	7.0	12.0	6.86	2.83	4.85
10,884	12	3.10	31.0	9.0	17.7	5.67	2.40	3.71
17,100	13	2.69	48.0	8.0	24.9	6.72	2.01	3.18
43,200	14	2.60	49.0	9.0	26.2	8.23	2.12	3.28
14,850	15	2.48	41.0	11.0	28.8	6.03	2.40	3.23
9,900	16	2.04	48.0	25.0	33.3	4.18	2.57	3.17
3,600	17	1.75	47.0	33.0	37.5	3.55	2.93	3.29
102,684	.....	2.56	.....	.....	26.0	.....	.....	3.33
4,500 broilers	.....	1.62	.....	.....	42.8	.....	.....	2.79

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1,350	.....	.....	9.31	.....	.....	3.03	.....	.....	12.34
1,800	15.94	6.61	11.28	5.34	1.98	3.66	21.28	8.59	14.94
10,884	13.45	5.70	8.59	3.70	1.36	2.32	17.15	7.07	10.91
17,100	14.70	4.75	7.30	4.71	1.28	2.11	19.41	6.03	9.41
43,200	18.00	4.38	6.99	4.00	1.09	1.85	22.00	5.81	8.84
14,850	13.47	5.51	6.59	4.04	1.37	2.40	17.51	6.88	8.99
9,900	8.28	4.75	6.35	2.69	1.39	1.88	10.97	6.14	8.23
3,600	6.60	5.38	6.01	1.97	1.58	1.80	8.56	6.96	7.81
102,684	.....	.....	7.20	.....	.....	2.00	.....	.....	9.20
4,500 broilers	.....	.....	5.09	.....	.....	1.58	.....	.....	6.67

A study of Table 4 shows that the cost of gains increased as the season advanced, due both to the increased size of the birds and to less favorable weather conditions for fattening. The greatest and cheapest gains were made on small birds during the summer and early fall. Very hot weather increased the cost of gains slightly, while cold, cloudy, changeable weather in the fall raised the cost materially. Except for a few minor fluctuations, due to extremely hot weather, the cost of gains was comparatively steady during July, August, and September, after which time it increased quite rapidly. Broilers made the highest, cheapest gains. One lot of roasters (lot 82) which weighed 5 pounds to the bird gained only 9 per cent, while the total cost of a pound of gain was 11.97 cents. The average gain of the broilers was 42.8 per cent, and the average cost of gain 6.67 cents a pound. The lots containing the greatest per cent of light-weight chickens made the cheapest gains, while the average cost of gains varied inversely with the average weight of the lots.

The gain per 100 head in fattening may be shown in two ways—by the per cent of gain or by the gain in actual weight. The per cent of gain throughout the feeding season varies inversely with the average weight of the lots, so that a gain of 30 per cent on a lot averaging 1.5 pounds per head is no greater in actual pounds than a gain of 15 per cent on a lot of the same number of birds weighing 3 pounds per head. The total gain per 100 head is more constant throughout the feeding season, and on that account this method of recording gains is preferred by some companies, as the average weight of the birds does not have to be known when comparing the gains at different periods.

EXPERIMENT B, 1912.

The ration by months in 1912 at Station 1 was as follows: August, 1 part of shorts, 2 parts of low-grade wheat flour, 4 parts of corn meal, and 5 per cent of tallow, mixed with 72.5 per cent of buttermilk; September, 1 part of shorts, 2.5 parts of low-grade wheat flour, 4.5 parts of corn meal, and 5 per cent of tallow, mixed with 68 per cent of buttermilk; October and November, 1 part of shorts, 4 parts of low-grade wheat flour, 5 parts of corn meal, and 5 per cent of tallow, with 63 per cent of buttermilk. In general the proportion of shorts to low-grade wheat flour decreased, while the proportion of low-grade wheat flour to corn meal increased as the season progressed. This ration is quite similar to the one used during part of the season of 1911 at this station, and also to the one used in Experiment C at Station 4, except that it contains 5 per cent of tallow, which was not fed at Station 4. A much larger per cent of buttermilk was used in mixing the ration at this station than at Station 4 during the warm weather. This larger per cent of buttermilk appears to be especially advantageous in warm weather. A small amount of oatmeal, which was infested with

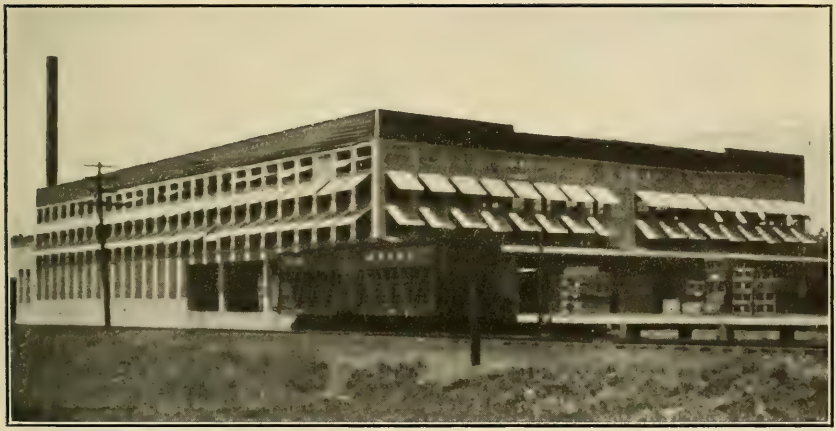


FIG. 1.—FEEDING STATION NO. 4, A WELL-EQUIPPED PLANT.

Note complete ventilation, easily controlled.

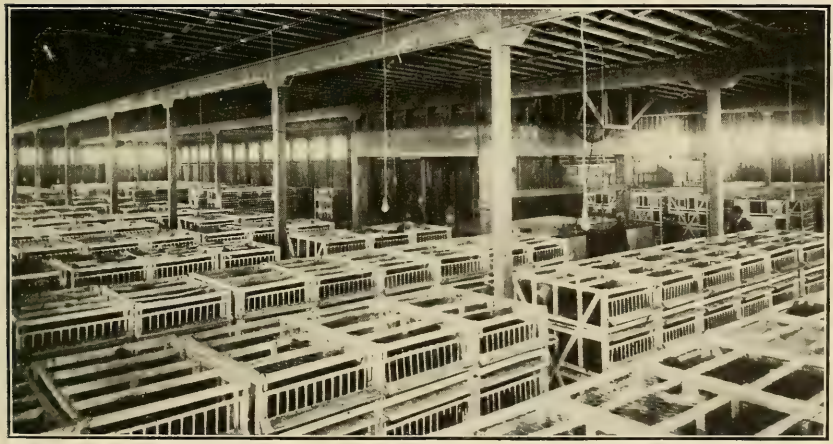


FIG. 2.—INTERIOR OF STATION NO. 4, SHOWING GENERAL ARRANGEMENT, FEED MIXERS, AND ELEVATOR

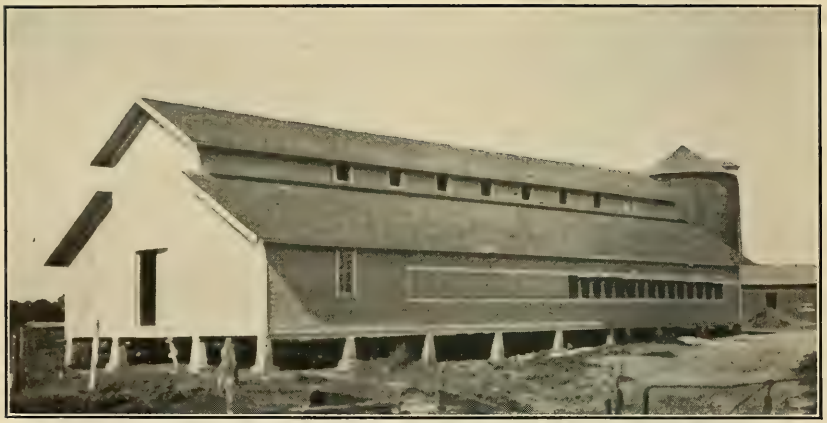


FIG. 1.—A SMALL FATTENING STATION WITH FEED ROOM IN THE REAR.

FIG. 2.—STATIONARY FEEDING BATTERY USED IN FEEDING STATION NO 1.

weevils, was bought at $1.50 per 100 pounds, and fed with good results to four lots in this experiment. Oatmeal gives slightly greater gains than low-grade wheat flour, but does not produce as economical gains at the present relative market prices of these two grains.

The broilers and roasters were not separated at this station, but the average cost of gain at this station would undoubtedly have been reduced after the middle of October if the lots had been fed for a shorter period. The longer feeding at that time of the year produced a better quality of flesh, but at a rather excessive cost compared with the cost earlier in the season on smaller chickens. No cripples or birds off feed were removed from the lots during this year, as has been the custom in previous seasons. The results for the season were very satisfactory.

TABLE 5.—*Summary of Experiment B, 1912, Station 1, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
900	9	3.60	.....	.....	7.0	.....	.....	5.74
5,400	10	2.73	28.0	4.0	13.7	10.19	2.36	5.59
2,700	11	2.55	34.0	10.0	19.7	5.00	1.94	3.49
5,400	12	2.52	31.0	14.0	22.2	4.55	2.35	3.24
17,100	13	2.10	51.0	14.0	30.1	5.35	1.89	2.90
27,900	14	2.22	52.0	10.0	29.6	7.38	2.07	3.32
10,800	15	2.51	35.0	15.0	23.4	5.37	2.83	4.04
10,800	16	2.57	34.0	19.0	25.3	4.25	2.69	3.84
5,400	17	2.43	45.0	22.0	29.7	4.31	2.69	3.69
3,600	18	2.34	38.0	32.0	34.8	3.56	3.12	3.39
90,000	.....	2.36	.....	.....	26.7	.....	.....	3.58

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
900	.....	.....	11.54	.....	.....	3.30	.....	.....	14.84
5,400	20.49	5.71	11.57	6.25	1.57	3.51	26.74	7.28	15.08
2,700	10.06	4.68	7.29	3.05	1.44	2.10	13.11	6.12	9.39
5,400	9.14	5.70	6.85	2.19	1.48	1.70	11.33	7.18	8.55
17,100	10.76	4.57	6.57	2.33	1.18	1.65	13.09	5.75	8.22
27,900	14.84	5.00	7.08	3.50	1.14	2.10	18.34	6.19	9.18
10,800	10.79	6.51	8.75	2.52	1.66	2.04	13.31	8.17	10.79
10,800	9.77	5.75	8.31	2.28	1.13	1.80	12.23	6.88	10.11
5,400	9.21	6.18	8.05	2.18	1.41	1.68	11.39	7.59	9.73
3,600	7.62	7.17	7.35	1.50	1.41	1.46	9.12	8.88	8.81
90,000	.....	.....	7.70	.....	.....	1.99	.....	.....	9.69

EXPERIMENT C, 1911.

This experiment was conducted at Station 4, of which exterior and interior views are shown in Plate I. The number of birds fed during the season totaled 117,151, which included 17,330 broilers and 55,010 roasters. The results for all the birds are summarized in Table 6 according to number of days fed, and the average results for the broilers and roasters, irrespective of length of feeding period, are shown separately as in the other experiments.

FEED.

A ration composed of about 1 part of shorts, 2 of low-grade flour, and 3 of corn meal was fed until August 12, when it was changed to 1 part of shorts, 1 of flour, and 2 of meal. On August 23 another change was made to 1 of shorts, 2 of flour, and 4 of meal, which was again changed on October 8 to 1 of shorts, 3 of flour, and 9 of meal, which was fed to the end of the season. The gains and cost were quite consistent, as the variation was due largely, if not entirely, to conditions other than feed. Chickens will use a larger per cent of corn meal more efficiently during cool weather, as the feeding season progresses. These records show a marked decrease in gains during the hot weather in August, and an extremely high cost of gains during November and December. The poor results obtained in August were due partly to overcrowding and perhaps partly to feeding a mixture which was too thick during the extremely hot weather.

TABLE 6.—*Summary of Experiment C, 1911, Station 4, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
3,326	7	3.22	8.0	3.0	4.6	10.82	5.18	9.03
6,140	8	2.90	25.0	8.0	13.6	5.40	1.96	3.91
9,830	9	3.01	18.0	5.0	12.2	9.43	3.12	4.79
15,342	10	2.91	25.0	3.0	14.5	14.76	2.31	5.13
16,864	11	2.75	37.0	9.0	18.9	7.22	2.42	4.06
32,493	12	2.43	34.0	5.0	19.6	30.56	1.49	4.85
10,802	13	1.88	39.0	12.0	25.0	5.86	2.69	3.79
17,298	14	1.84	50.0	17.0	33.0	5.69	2.25	3.25
5,056	15	1.99	44.0	25.0	29.5	4.41	3.23	3.55
117,151		2.48			20.4			4.45
17,330 broilers		1.60			34.9			3.69
55,010 roasters		3.05			14.0			5.50

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
3,326	17.04	8.14	14.25	4.04	2.14	3.33	20.56	10.28	17.85
6,140	8.59	3.44	6.23	2.90	.76	1.45	11.49	4.20	7.68
9,830	15.04	5.48	7.74	4.80	1.20	1.92	19.84	6.68	9.66
15,342	28.27	3.92	8.19	9.03	.89	2.15	37.30	4.81	10.34
16,864	11.33	4.06	6.68	2.39	.89	1.43	13.72	4.95	8.11
32,493	49.00	3.84	7.91	13.52	.98	1.96	62.52	4.82	9.87
10,802	9.91	4.20	6.23	2.34	1.19	1.65	11.92	5.49	7.88
17,298	9.12	3.62	4.80	4.30	.98	1.54	13.04	5.29	6.34
5,056	7.08	5.77	6.04	1.65	1.23	1.50	8.58	7.03	7.54
117,151			7.15			1.81			8.96
17,330 broilers			5.98			1.63			7.61
55,010 roasters			8.83			2.12			10.95

Table 6 shows the common custom of separating roasters and broilers, feeding the former for short periods and the latter for a longer time. The broilers produced cheaper gains with less feed than the roasters, the average total cost per pound of gain being 1.89 cents less. Weather conditions were more favorable when most of the broilers were fed, which gives them an advantage over the roasters. Broilers fed during cool weather in summer produced the cheapest gains, but the gains later in the season, though cheaper than those produced by roasters, were much higher than earlier in the season, because a large number of the broilers were stunted and the weather conditions unfavorable.

The very marked increase in cost of gains in this experiment during November and December shows plainly the effect of weather conditions on the birds and the unprofitableness of feeding when this happens. It may be seen from Table III of the appendix that an unusually large proportion of dead birds are recorded in this experiment toward the close of the season. Comparing the results at this station with those obtained in Experiment D at Station 2, we find that the average gain and the amount of feed per pound of gain was the same for the season, while the cost was slightly greater at the latter station, due to the higher cost of the buttermilk. Condensed buttermilk diluted with 1½ parts of water was used in Experiment D, while the regular buttermilk, which was used in Experiment C, cost only 1½ cents per gallon. The proportion of corn meal in the ration was increased in cool weather without any injurious effects, but a study of the results indicates that a smaller per cent of corn meal in the ration produced cheaper gains.

EXPERIMENT C, 1912.

The ration at Station 4 in 1912 varied considerably during the season but on the whole was quite similar to that used in 1911, except that a smaller proportion of shorts was used throughout the season while a larger proportion of low-grade wheat flour was used during the latter part of the season. From 1 to 2 per cent of meat and bones was fed during the last half of June, throughout August and during the first half of September. The ration by months was as follows: July, 1 part of shorts, 3 parts of low-grade wheat flour, 6.5 parts of corn meal, mixed with 65 per cent of buttermilk; August, 1 part of shorts, 2 parts of low-grade wheat flour, 4 parts of corn meal, mixed with 67.5 per cent of buttermilk; September, 1 part of shorts, 4 parts of low-grade wheat flour, 7 parts of corn meal, mixed with 62 per cent of buttermilk; October, 1 part of shorts, 5 parts of low-grade wheat flour, 6.5 parts of corn meal, mixed with 62 per cent of buttermilk; November, 1 part of shorts, 6.5 parts of low-grade wheat flour, 11 parts of corn meal, mixed with 62 per cent of buttermilk.

The lots which averaged to weigh less than 1¾ pounds per bird were classed as broilers during the first part of the feeding season and the broilers and roasters were separated and fed different feeding periods after the 1st of October.

TABLE 7.—*Summary of Experiment C, 1912, Station 4, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
11,360	7	2.47	18.0	14.0	16.2	3.69	2.64	3.00
25,600	8	2.46	22.0	12.0	18.5	4.28	2.75	3.10
17,360	9	2.57	29.0	9.0	18.5	5.88	2.78	3.51
27,440	10	2.22	30.0	10.0	20.1	5.83	2.39	3.42
30,880	11	2.28	34.0	12.0	20.4	5.19	2.72	3.75
41,320	12	2.13	40.0	6.0	20.2	12.60	2.58	4.50
24,640	13	1.93	37.0	7.0	22.9	7.83	2.75	4.24
6,800	14	1.65	39.0	25.0	28.8	4.95	2.80	3.64
2,720	15	1.70	37.0	27.0	32.7	5.41	3.03	3.83
2,800	16	1.66	38.0	23.0	33.0	4.78	3.18	3.96
211,560	.....	2.21	.....	.....	20.7	.....	.....	3.72
43,120 broilers	.....	1.64	.....	.....	26.8	.....	.....	4.02
26,880 roasters	.....	3.10	.....	.....	11.7	.....	.....	5.73

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
11,360	6.39	4.67	5.33	1.05	0.82	0.89	7.44	5.49	6.22
25,600	7.64	4.84	5.49	1.21	.77	.88	8.85	5.61	6.37
17,360	10.47	4.88	6.22	1.85	.75	.99	12.32	5.63	7.21
27,440	9.73	4.18	6.13	2.10	.80	1.33	11.80	5.02	7.46
30,880	9.14	4.80	6.63	1.74	.88	1.31	10.73	5.68	7.94
41,320	23.89	4.62	7.93	6.37	1.01	1.75	30.26	5.63	9.68
24,640	13.80	4.93	7.54	2.52	1.04	1.68	16.32	6.01	9.22
6,800	8.09	5.03	6.51	2.91	1.09	1.55	10.30	6.12	8.06
2,720	9.64	5.52	6.92	2.36	1.70	2.14	11.34	7.88	9.06
2,800	8.52	5.82	7.20	2.87	1.47	2.12	11.34	7.78	9.32
211,560	.....	.....	6.61	.....	.....	1.37	.....	.....	7.98
43,120 broilers	.....	.....	7.25	.....	.....	1.74	.....	.....	8.99
26,880 roasters	.....	.....	9.78	.....	.....	1.89	.....	.....	11.67

EXPERIMENT D, 1911.

The results of this experiment at Station 2 were quite even throughout the season, except that during the month of November there was a marked increase and great variation in the cost of gains. The lots were handled like those in Experiment C, except that roasters were fed 7 or 8 days, while broilers were on feed 14 days. This method is open to criticism because cheaper gains are produced by gradually decreasing the length of the feeding period on roasters, reaching 7 or 8 days about the middle of October, than by changing from 14 directly to 7 or 8 days as soon as the lots are separated into roasters and broilers. However, much depends on the weather conditions, on the market, and on the economy of labor in the feeding station.

FEED.

The ration throughout the season consisted of 3 parts of corn meal, 2 parts of low-grade flour, and 5 per cent of shorts, mixed with condensed buttermilk diluted with 1½ parts of water. The results plainly show that these proportions of corn meal and flour make a very satisfactory ration throughout the feeding season. The condensed buttermilk undoubtedly offsets the corn meal in this ration during hot weather, so that it is more satisfactorily fed with thick condensed buttermilk than if mixed with the ordinary buttermilk.

TABLE 8.—*Summary of Experiment D, 1911, Station 2, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
9,174	6	3.31	9.0	2.0	7.4	14.31	3.45	5.25
14,670	7	3.20	13.0	2.0	9.2	16.74	3.15	5.58
35,462	8	2.96	19.0	8.0	13.4	6.24	2.68	3.93
11,012	9	2.89	22.0	7.0	14.8	6.96	2.62	4.01
5,570	10	2.40	25.0	12.0	20.1	4.92	2.72	3.35
2,172	13	2.21	37.0	28.0	29.7	4.09	2.89	3.11
15,230	14	1.94	42.0	19.0	30.4	5.54	2.85	3.82
11,810	15	1.97	41.0	23.0	30.2	5.13	2.92	3.71
3,340	16	1.97	32.0	26.0	27.4	4.21	3.73	4.10
1,360	17	1.80	.....	.....	37.0	.....	.....	3.38
109,800	.....	2.68	.....	.....	18.0	.....	.....	4.18
11,500 broilers	.....	1.79	.....	.....	36.9	.....	.....	4.27
71,928 roasters	.....	3.04	.....	.....	12.0	.....	.....	4.48

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
9,174	30.86	7.48	11.12	6.72	1.34	2.27	37.58	8.89	13.39
14,670	35.31	6.79	11.63	6.80	1.15	2.04	42.11	8.05	13.67
35,462	13.60	5.59	8.31	2.31	.95	1.40	15.37	6.54	9.71
11,012	14.47	5.26	8.51	2.50	1.01	1.44	16.97	6.27	9.95
5,570	10.13	5.31	6.77	1.81	.98	1.22	11.94	6.30	7.99
2,172	9.98	5.97	6.37	1.93	1.14	1.24	11.91	6.93	7.61
15,230	12.29	5.67	7.80	2.26	1.06	1.43	14.55	6.73	9.23
11,810	10.87	5.76	7.49	1.73	1.11	1.42	12.56	6.87	8.91
3,340	8.43	7.35	8.17	1.73	1.43	1.66	10.16	8.78	9.83
1,360	.....	.....	6.63	.....	.....	1.29	.....	.....	7.92
109,800	.....	.....	8.71	.....	.....	1.56	.....	.....	10.27
11,500 broilers	.....	.....	8.87	.....	.....	1.57	.....	.....	10.44
71,928 roasters	.....	.....	9.42	.....	.....	1.66	.....	.....	11.08

EXPERIMENT D, 1912.

The ration at Station 2 in 1912 was similar to that used in 1911, except that 2 to 3 per cent of bone and waste meat was fed at irregular intervals until the middle of September. A slightly larger (from 5 to 10) per cent of shorts was fed during 1912 after the middle of September, while this same per cent of a mixture of shorts and graham flour

was used up to that time. The supply of condensed buttermilk was very limited, so that it was necessary to dilute it with a larger per cent of water as the feeding season advanced. The amount of condensed buttermilk fed per 100 pounds of grain was as follows: 10 gallons in August, 7 gallons in September, 4.5 gallons in October, and 3.3 gallons in November. The rather poor results secured at this station during the last part of the season may have been partly due to this lack of buttermilk, but the results were quite variable throughout the entire season.

The cost of feed was considerably higher in 1912 than in 1911. The broilers and roasters were not separated at this station during this feeding season. The high cost of the gains during October on lots fed from 11 to 15 days would indicate that the common practice of dividing the lots into broilers and roasters about the 1st of October and gradually reducing the length of the feeding period of the latter was more profitable than to feed roasters for 14 days after the 1st of October.

TABLE 9.—*Summary of Experiment D, 1912, Station 2, arranged according to length of feeding period.*

Number of head.	Days fed.	Average weight.	Per cent of gain.			Grain per pound of gain.		
			High.	Low.	Average.	High.	Low.	Average.
		Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
14,632	6	3.35	15.0	5.0	7.5	7.22	2.67	5.37
8,986	7	3.04	21.0	6.0	12.4	7.88	2.52	4.58
8,032	8	2.78	26.0	6.0	13.2	7.81	2.20	5.29
6,748	9	2.98	26.0	7.0	12.1	6.59	2.46	5.15
14,018	10	2.55	24.0	9.0	20.6	6.76	3.40	3.99
24,830	11	2.45	27.0	6.0	17.8	12.33	2.70	4.65
7,056	12	2.54	23.0	9.0	15.9	8.69	3.02	5.22
5,610	13	2.79	18.0	7.0	15.1	11.70	4.04	6.18
7,320	14	2.38	23.0	13.0	18.4	8.15	2.83	5.34
5,340	15	2.43	25.0	8.0	17.5	11.64	3.74	6.66
3,840	16	1.87	30.0	22.0	25.8	4.99	3.79	4.38
640	17	1.73	.....	.....	35.0	.....	.....	3.78
107,052	.....	2.69	.....	.....	15.7	.....	.....	4.98

Number of head.	Total cost of feed per pound of gain.			Cost of labor per pound of gain.			Total cost per pound of gain.		
	High.	Low.	Average.	High.	Low.	Average.	High.	Low.	Average.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
14,632	13.82	5.22	9.90	3.16	0.77	2.08	16.87	5.99	11.98
8,986	13.60	5.17	8.10	2.99	0.78	1.38	16.59	5.95	9.48
8,032	14.60	4.79	10.15	3.28	0.78	1.78	17.88	5.57	11.93
6,748	11.37	5.51	11.59	1.81	1.00	1.54	13.13	6.54	13.13
14,018	12.90	6.82	7.99	1.98	0.81	0.99	14.88	7.63	8.98
24,830	22.75	6.14	9.68	3.64	1.16	1.56	26.22	7.30	11.24
7,056	15.58	6.83	10.27	2.27	1.16	1.66	17.85	8.03	11.93
5,610	27.20	9.21	11.78	4.50	1.31	1.64	31.70	10.75	13.42
7,320	15.60	6.48	11.21	2.19	1.12	1.70	17.62	7.60	12.91
5,340	21.56	8.73	13.05	2.92	1.38	1.98	24.48	10.11	15.03
3,840	11.67	8.90	11.21	1.83	1.36	1.59	13.50	10.26	12.80
640	.....	.....	8.78	.....	.....	1.36	.....	.....	10.14
107,052	.....	.....	9.95	.....	.....	1.59	.....	.....	11.54

DETAILS CONCERNING THE FEEDING.

LENGTH OF THE FATTENING PERIOD.

No comparison can well be made from these tables between the lots fed different lengths of time. For instance, in Experiment B (Table 4) the 17-day lots show the cheapest gains, and the cost of gains happened to increase as the length of the feeding period decreased; but this was due either to the difference in the weight of the birds or to the time of the year when they were fed, and not to the number of days fed. The small birds were fed for the longer feeding periods and during the best weather for fattening, while the large birds were fed for the shorter periods, during the poorest part of the feeding season, which condition produced the cheapest gains on the lots fed for the longest feeding periods. The cost of gain on a given lot increases directly with the length of the feeding period.

In this experiment shortening the length of feeding earlier in the fall would undoubtedly have cheapened the cost of gain, but as the manager wanted to produce an especially fine quality of flesh, he considered it advisable to feed for the longer period while the chickens did well in the feeder. When the results showed that the lots were losing by being kept on feed 14 days, the period was shortened as quickly as possible without complicating the labor problem in the packing house. This shows the need of planning for the increased cost of gain in the fall, and preparing for it by shortening the length of feeding previous to the period of low gains, as the labor can not be handled economically if an abrupt change is made.

Again, in Experiment C the best length of feeding period can not be determined from a comparative study of the feeding, on account of a variation in the size of the birds and in the weather conditions for lots fed the same number of days. A comparison of the results at the various stations shows that the common practice of feeding broilers and springs for about 14 days during the first part of the feeding season and separating the lots of roasters and broilers about the middle of September, while gradually reducing the feeding period of the roasters, is the most profitable practice, unless there is a special reason for feeding the lots longer in the fall.

FEEDING TWICE AS AGAINST THREE TIMES DAILY.

Comparing the feeding results secured in Table 4 (Experiment B, Station 1) with those in the other tables, we find that the feed at this station was apparently more efficient than at any of the other stations. Practically the same gains were secured, both with less daily consumption of feed and less feed per pound of gain. Various factors might have influenced these results, but it would appear that by feeding twice instead of three times daily the grain was used more efficiently

in producing gains. At Station 1 during the greater part of the season the birds received a light feed in the morning and a heavy feed at night, thus getting the bulk of their feed in one meal. Some small tests in cramming, the results of which were not recorded, produced very good results by feeding only once daily. The advantage of feeding twice as against three times daily depends on other factors as much as on the efficiency of the use of feed, so that each feeder must decide that question for himself. Very good results can be secured by either method. There appears to be less danger of overfeeding when feeding only twice daily, but a more experienced feeder is required to regulate the amount to feed in two meals than in three in order to get the greatest amount of feed into the bird. Apparently under average conditions the birds will consume more feed in three meals daily, but will use their feed more efficiently if fed twice, provided that they receive enough feed.

THE USE OF CONDIMENTAL FEEDS.

A commercial preparation claimed by the manufacturers to stimulate the appetites of birds which are being fattened was fed in Experiment B to lots 1 to 12. Later in the season the test was repeated by feeding this preparation to lots 23 to 37. It did not appear to stimulate the birds' appetites, as the gains of other lots, fed before and after those which received this substance, did not show there was any advantage in feeding it.

Oil of aniseed mixed with pure carbolic acid, and fed at the rate of one tablespoonful to every 2,000 birds, had been used by one of the feeders in some previous work. It was claimed to have increased the appetite of the birds, but it made the bones brittle, so that its use prevented good dressing.

THE USE OF SALT AND GRIT.

Fine salt was fed in Experiments C and D at the rate of 4 pounds of salt to 10,000 head, without producing any apparent results. The feeders at these stations believed that salt in the feed kept the birds from picking each other, so that when this vice is prevalent it may pay to feed salt, otherwise there is no advantage in adding salt to the ration.

Grit was given to the birds in Experiment B twice weekly during the first month of the feeding season, but no grit was fed at any of the other stations. At the end of the month the feeding of grit was stopped without any apparent effect, and was not fed any more during the season. Birds in good health which are fattened not longer than 16 days do not need grit, as grit increases the cost of feed and labor without producing better gains.

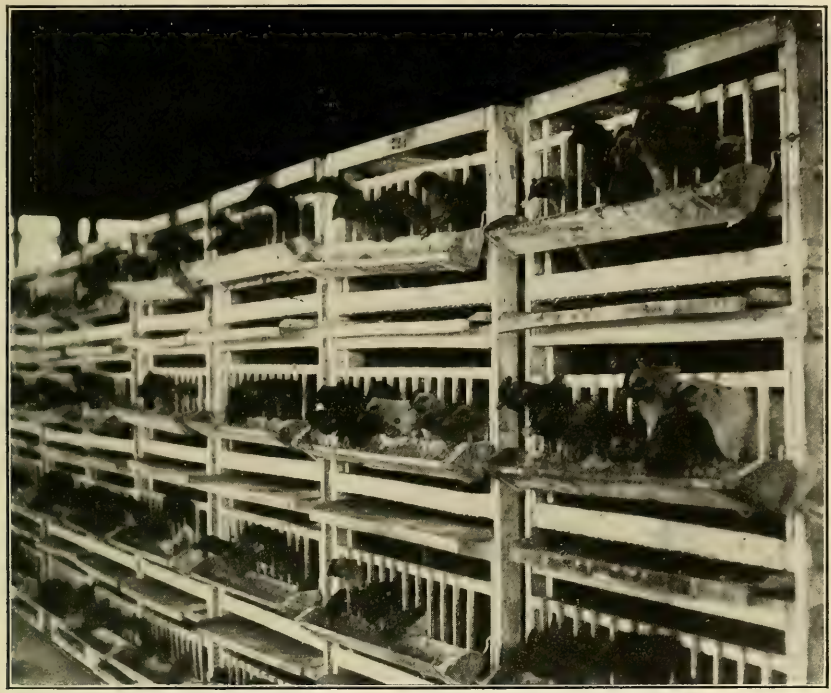


FIG. 1.—CHICKENS IN FEEDING BATTERIES WAITING TO BE FED.

FIG. 2.—POURING THE FEED INTO THE TROUGHS.

THE EFFECT OF BUTTERMILK ON MOLTING.

The marked growth of feathers which occurs during a few days of fattening indicates that buttermilk and forced feeding tend to renew feathers rapidly. Chickens which do well in fattening are almost invariably covered with pin feathers, and this is an indication of good results in the feeder. Apparently a large amount of buttermilk in the feed greatly stimulates the growth of feathers, which fact might be noted in connection with the feeding of laying hens during the late summer to promote rapid molting and the growth of new feathers without forcing the birds.

THE BLEACHING EFFECT OF CONDENSED BUTTERMILK.

The No. 1 grade of poultry ordinarily sells for 1 to 2 cents more per pound than the third grade, so that a feeding mixture which will produce a greater per cent of the No. 1 grade has a commercial value. Buttermilk in the feed produces a bleach. An experiment was conducted at Station 4 to see whether the addition of condensed to ordinary buttermilk was profitable. One gallon of condensed buttermilk was added to 10 gallons of ordinary buttermilk from August 24 to September 18, and this test was repeated from October 4 to the 18th. The birds, as shown by Table III of the appendix, did not do well during the hot weather, which occurred about the middle of August. This is also shown in the grading reports. Condensed buttermilk was fed at this time and resulted in an immediate marked increase in the fancy grades of dressed poultry. This increase was greater than the relative increase in per cent of gain, showing that the increased consumption of buttermilk produced a larger per cent of fancy poultry, but when this condensed buttermilk was dropped out of the ration on September 18, the proportion of fancy poultry did not decrease. This would appear to show that the addition of extra condensed buttermilk was profitable only during warm or hot weather, and in fattening small birds. Condensed buttermilk was used entirely in mixing the feed at Stations 2 and 3, adding 1½ gallons of water to 1 gallon of the milk at Station 2 and equal parts of water and condensed buttermilk at Station 3. This large proportion of milk solids showed very marked results in producing a bleach in the poultry.

MISCELLANEOUS RATIONS.

A test in cramming chickens, conducted by the feeder at Station 1, on ground Georgia peanuts with buttermilk, produced unfavorable results. The feed was very laxative, and the chickens, though eating well, grew thin instead of fat. A ration containing about 6 per cent of peanut meal gave good results. The peanuts flavored the flesh and produced a peanut-fed chicken which sold at a special price, but the unfavorable effects of feeding a large per cent of peanut meal made this ration impractical.

A ration consisting of 60 per cent steel-cut oats, 40 per cent corn meal, with three-fourths of a pound of tallow and half a pound of fresh meat per 100 head daily, mixed with buttermilk, gave very good results, producing extremely fat chickens. The oats were soaked in buttermilk a couple of hours before feeding.

A test was made of cooked meal obtained by adding boiling water to corn meal and allowing this mixture to stand for 12 hours. Some condimental foods were added to this feed, and milk was kept before the birds during the day, but the results were not particularly satisfactory.

Another test was made with low-grade flour in place of the steel-cut oats, and this produced almost as high gains at $2 less cost per 100 head on feed. Table or cottonseed oil which cost 45 to 55 cents per gallon was tried in place of tallow. Chopped green alfalfa was added to the ration, but alfalfa has a tendency to color the flesh if fed up to killing time. None of these extra feeds appear to be either necessary or economical.

THE FEED AS AFFECTED BY CHANGES IN THE WEATHER.

The milk was heated before mixing with the feed at the different stations as soon as the weather turned cold in the fall. The consistency of the feed depends greatly on the weather. During hot weather the mixture should be made so that it will run rather than drip. In cooler weather it can be mixed with less milk to good advantage, but should drip freely. When thick condensed buttermilk is used, the feed can be mixed to a thicker consistency than with ordinary buttermilk. The monthly average of the per cent of buttermilk to total feed at Station 1 (Experiment B) was as follows: July, 67 per cent; August, 70 per cent; September, 68 per cent; October, 65 per cent, and November, 66 per cent. The daily variation in the per cent of milk was quite marked, especially in July and August.

NUMBER OF BIRDS IN EACH COMPARTMENT.

From 8 to 12 birds were placed in each compartment of the portable batteries at Stations 2, 3, and 4. Twelve birds were too many, as the birds scratched each others' backs through attempting to feed at the same opening. Ten birds gave good satisfaction at all of the stations, but 8 birds seemed to do better at Station 4 during hot weather. Ten birds in a compartment allows nine-tenths of a foot of floor space per bird in the battery. Later in the season, when the birds were larger, only 8 birds were placed in each compartment. Batteries of the size mentioned (2 feet 4 inches wide by 3 feet 10 inches long) will hold 80 broilers or medium-sized springs or 64 large springs or roasters without crowding, but in very hot weather it may pay to place only 64 head in each battery, if enough floor space is available.

REMOVING BIRDS "OFF FEED."

"Cripples" were removed from the batteries at Station 1 after October 26, which materially lowered the loss due to dead birds, but increased the cost of labor. These birds, if in good flesh, were dressed and their weight credited to their respective lots. The economy of this extra labor depends upon numerous conditions which are closely related. One reason for doing this at Station 1 and not at the other stations was that the birds were fed there for a longer time much later in the season than at the other stations. The conditions in the feeding station appeared to produce more sickly birds at Station 1 than at the others. If the chickens are carefully selected before they are put into the feeding station, so that no birds with colds or apparently out of condition go into the feeder, and they are only fed for a short period of 6 to 10 days under proper conditions of ventilation, it does not appear profitable to employ an extra man to remove "cripples." The regular help, however, must watch the birds carefully enough to prevent roupy conditions from spreading through the coops, although this is not likely to occur during the short feeding periods. Portable batteries placed a few inches apart keep the birds scattered so that any contagious disease will not spread as rapidly as in stationary coops or batteries.

FEATHER PICKING.

Two per cent of linseed meal was fed with the ration in Experiment D from September 1 to November 5. The linseed meal did not appear to affect the results of fattening in any way. The chickens during this period dressed particularly well, and it is possible that this linseed meal made picking easier, but its use would not be profitable for this purpose. The object of feeding linseed meal was to see if it had any effect on the habit of chickens picking each other. This vice caused considerable loss in fattening at times, but appeared to depend greatly on the condition of the chickens before they reached the packing house. Chickens which have not been well fed, or have been held for some time by the country merchant under poor conditions, are particularly subject to this vice, while in sections where the birds receive better care and are moved more quickly from the farm to the packing house, this habit does not cause any particular loss. Linseed meal added to the ration at Station 4 seemed to stop this vice, but the habit was not so widespread that a good test could be made. Either fresh meat or good beef scrap might prove of value where there was much loss due to this habit, but the remedy appears to lie largely in the use of better methods of handling the chickens before they reach the fattening stations.

Feather picking was more prevalent at all of the feeding stations in 1912 than it has ever been before. From 2 to 3 per cent of waste

meat, and bones from local butcher shops was fed at Stations 2, 3, and 4 at irregular intervals during the season, but no consistent effect was noticed from this special feeding. Several lots at Station 3 were fed specially prepared mixed feeds which were claimed to prevent feather picking, but the results were inconsistent. The feather picking broke out during a period of cool weather, while the birds were eating ravenously, but stopped quite suddenly when the weather became warm and the birds were not so eager for their food. There appeared to be less loss due to this trouble where the largest per cent of buttermilk was fed in the ration, but feather picking can not be entirely controlled by regulating the proportion of buttermilk in the feed. Less heating rations, or those containing a large per cent of shorts and mixed feed and a small per cent of corn meal, make the best feeds for use in hot weather where feather picking is prevalent. The mixed feeds, however, produced chickens covered with small pin feathers, which resulted in a poorer grade of dressed product, and therefore made the feeding of the mixed feeds unprofitable as well as undesirable.

FATTENING HENS.

The results of fattening over 20,000 hens are shown in Tables 10 and 11, the feeding having been done at Stations 1, 2, and 4. All the lots were fed during November, 1911, and November and December, 1912.

The hens at Station 1 were fed coarse corn chop, or cracked corn with the meal left in, and 15 per cent of shorts, mixed with buttermilk. The shorts were added to facilitate mixing the feed, otherwise the corn chop would sink to the bottom of the mixer. The feed was mixed with considerable buttermilk and fed in a wet state.

The regular chicken mixture was fed to the hens at Stations 2 and 4, which, while producing slightly smaller gains, was apparently more efficient, as the average gain was produced with a pound less grain than with the corn chop, shorts, and buttermilk in 1911. It should be stated, however, that the increased cost of gain at Station 1 was due partly to the increased cost of buttermilk at this station, as the cost of grain in the rations was about the same, the regular chicken rations being slightly cheaper than the corn-chop ration. The comparative difference in cost of labor is due to the condition explained under Experiment B. A comparison of the results in 1912 does not show any marked advantage of one ration over the other

TABLE 10.—*Experiments in fattening hens, 1911.*

STATION 1.

Lot.	Number in.	Total weight in.	Average weight in.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Grain per 100 head.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
	Head.	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1	348	1,081	3.1	9	800	1,290	209	19.3	60	3.83	6.00	1.67	7.67
2	392	1,319	3.4	9	800	1,441	122	9.2	31	6.56	10.41	2.87	13.28
3	1,170	3,469	3.0	9	2,500	3,902	433	12.5	37	5.77	8.95	2.72	11.67
4	392	1,338	3.4	10	900	1,490	152	11.4	39	5.92	9.49	2.58	12.07
5	392	1,242	3.2	10	900	1,425	183	14.7	47	4.92	7.71	2.14	9.85
6	784	2,536	3.2	10	2,000	2,870	334	13.2	43	5.99	9.28	2.34	11.62
7	392	1,288	3.3	12	1,100	1,492	204	15.8	52	5.39	8.36	1.92	10.28
Average	.....	.....	3.17	.....	.....	.....	.....	13.4	.....	5.61	8.77	2.41	11.18

STATION 4.

1	378	1,284	3.4	7	438	1,422	138	10.7	37	3.17	5.07	1.31	6.38
2	330	1,152	3.5	8	439	1,275	123	10.7	37	3.57	5.66	1.42	7.08
3	384	1,320	3.4	8	526	1,465	145	11.0	38	3.63	5.74	1.83	7.57
4	256	867	3.4	8	343	934	67	7.7	26	5.12	8.18	2.87	11.05
5	448	1,477	3.3	9	672	1,646	169	11.4	38	3.98	6.31	1.54	7.85
6	320	1,084	3.4	9	483	1,198	114	10.5	36	4.24	6.83	1.91	8.74
7	192	781	4.1	9	330	823	42	5.4	22	7.86	12.29	2.79	15.08
8	128	480	3.8	10	247	540	60	12.5	47	4.12	6.45	1.50	7.95
9	256	928	3.6	10	428	1,020	92	9.9	36	4.65	7.49	2.12	9.61
10	261	978	3.8	10	485	1,128	150	15.3	58	3.23	5.05	1.03	6.08
Average	.....	.....	3.51	.....	.....	.....	.....	10.6	.....	4.16	6.61	1.77	8.38

TABLE 11.—*Experiments in fattening hens, 1912.*

STATION 1.

Lot.	Number of head.	Total weight.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Pounds.	*Pounds.*	1912.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
1	450	1,427	3.17	Nov. 21 to Nov. 27.	7	554	1,581	154	11	34	10	3.60	6.15	2.12	8.27
2	450	1,466	3.26	Nov. 22 to Nov. 28.	7	538	1,566	100	7	22	15	5.38	9.20	3.11	12.31
3	450	1,460	3.24	Nov. 24 to Dec. 1...	8	475	1,571	111	8	25	13	4.28	7.32	2.19	9.51
4	450	1,454	3.23	.....do.....	8	474	1,593	139	10	31	7	3.41	5.83	1.73	7.56
5	450	1,407	3.13	Nov. 27 to Dec. 3...	7	574	1,569	162	12	36	25	3.54	6.06	1.90	7.96
6	450	1,500	3.33	Nov. 29 to Dec. 5...	7	627	1,569	69	5	15	5	9.09	15.54	4.67	20.21
7	450	1,443	3.21	Dec. 5 to Dec. 11...	7	529	1,565	122	8	27	11	4.34	7.41	3.28	10.69
8	450	1,390	3.09	Dec. 6 to Dec. 12...	7	529	1,529	139	10	31	13	3.81	6.50	3.41	9.91
9	450	1,366	3.04	Dec. 10 to Dec. 16..	7	611	1,562	196	14	44	9	3.12	5.33	2.14	7.47
Average			3.19						9.4			4.59	7.70	2.73	10.43

STATION 2.

				1912.											
1	1,500	5,871	3.91	Nov. 10 to Nov. 18.	9	3,030	6,387	516	9	34	31	5.87	10.67	2.35	13.02
2	1,080	3,990	3.69	Nov. 12 to Nov. 18.	7	1,685	4,400	410	10	38	17	4.11	7.30	1.71	9.01
3	360	1,324	3.68	Nov. 13 to Nov. 19.	7	551	1,511	187	14	52	2	2.95	5.08	1.12	6.20
4	780	2,915	3.74	Nov. 14 to Nov. 20.	7	1,154	3,148	233	8	30	14	4.95	8.40	1.74	10.14
5	960	3,655	3.81	Nov. 15 to Nov. 21.	7	1,344	4,002	347	10	36	7	3.87	6.45	1.30	7.75
6	1,020	3,910	3.83	Nov. 16 to Nov. 22.	7	1,428	4,199	289	7	28	10	4.94	8.08	1.45	9.53
7	1,140	4,695	4.12	Nov. 17 to Nov. 24.	8	1,813	5,070	375	8	33	5	4.83	7.69	1.22	8.91
8	1,040	3,937	3.79	Nov. 19 to Nov. 26.	8	1,550	4,259	322	8	31	13	4.81	8.46	1.20	9.66
9	1,020	3,847	3.77	Nov. 21 to Nov. 28.	8	1,714	4,084	237	6	23	19	7.23	10.89	1.68	12.57
10	780	2,909	3.73	Nov. 20 to Nov. 28.	9	1,482	3,044	135	5	17	12	10.98	16.99	2.54	19.53
Average			3.83						8.2			5.51	9.16	1.67	10.83

Corn chop and buttermilk were fed to hens held for live shipment during the summer months, but in very hot weather the birds did better on a ration of corn chop with 8 per cent of low-grade flour and 5 per cent shorts, which was less heating than the corn chop alone. These lots were only held for a short time in hot weather, and the object of feeding was to prevent shrinkage rather than to produce gains. Some lots showed a slight gain, others held their own weight, while a few showed a small shrinkage.

Corn chop is difficult to feed, as it can not be mixed with milk and poured from a feeding pail, so that the labor of feeding this ration is greater than with the other ration. The corn chop not mixed with other grains is fed by taking up a scoopful of grain and milk together, and stirring the mixture frequently to prevent the corn from settling in the mixing tank or feeding pail. If tallow is used in the chicken mixture, the corn-chop ration might prove as economical as the other ration. The regular chicken mixture prevents shrinkage better in hot weather, is cheaper, requires less labor, and produces slightly more economical gains in feeding hens than the corn-chop ration.

LESS PROFIT IN FATTENING HENS THAN IN FATTENING CHICKENS.

The average cost of the hens into the feeder was 7.7 cents a pound in 1911 and 10.3 cents in 1912, so that a pound of flesh can be bought more cheaply than produced in the feeding station. Therefore it only pays to feed hens under certain conditions. The object in feeding hens at Station 1 was to supply a trade for "milk-fed" hens and to dispose of the light hens, which are somewhat of a drug on the market in the ordinary grades of dressed fowl. At Stations 2 and 4 the light hens and those which were covered with small pin feathers were selected for fattening. The latter kind would grow feathers rapidly, so that they would dress as fancy poultry after a week or ten days fattening.

A comparison of the results secured in fattening hens at these three stations is shown in Tables 10 and 11. The feeding was done in November and December. The average cost of fattening the hens in 1911 was 10.92 and 8.74 cents per pound of gain at Stations 1 and 4, respectively, and 10.43 and 10.83 at Stations 1 and 2, in 1912. This is lower than the corresponding cost of fattening chickens at these stations during the same months, but higher than the average cost of fattening for the season. However, it may be stated that the cost for fattening chickens at Station 4 during the greater part of November (see Table III, appendix) was abnormally high. In general the difference in the cost, if any, would be more than made up in the selling price. Therefore, as hens are bought and sold at a considerably lower price per pound, it is, as a rule, much more profitable to fatten chickens than to fatten hens.

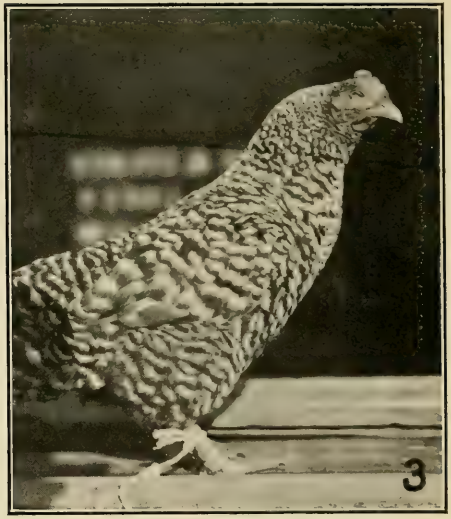
INDIVIDUAL VARIATION IN FATTENING CHICKENS.

A study of Table 12 and of the variation in the summaries of the feeding experiments at the different stations shows that many factors affect the gains in fattening. Variation within a lot is due somewhat to the difference in the weight of the birds, but largely to the difference in the ability of the individuals to take on flesh under the existing conditions. This plainly shows how much variation exists in this ability to fatten readily, and the influence which the weather has in fattening. The possible error of conclusions drawn from small lots in fattening experiments is readily noted, and this possibility undoubtedly occurs under other poultry methods, as in the influence of feed and housing on the production of eggs. The marked effects of weather on fattening demonstrates the error which may occur in direct comparison of fattening tests conducted at different periods of the year, or in different seasons.

TABLE 12.—*Individual variation in fattening chickens.*

Number of head.	Kind.	Average weight.		Number of days fed.	Per cent gain.		
		High.	Low.		High.	Low.	Average.
		Pounds.	*Pounds.*		*Per ct.*	*Per ct.*	*Per ct.*
1,790	Roasters..	4.19	2.58	8	36.4	4.5	13
1,400	...do.....	3.07	2.53	8	25.9	7.6	14
1,216	...do.....	3.05	2.70	8	27.0	9.0	14
1,880	Springs....	2.03	1.43	15	55.0	17.0	27
1,080	...do.....	1.95	1.62	14	63.0	18.0	29
768	Broilers...	1.89	1.69	14	56.0	12.0	36
320	...do.....	1.75	1.23	14	45.0	36.0	39
600	...do.....	1.65	1.50	14	53.0	18.0	38
480	...do.....	1.76	1.40	14	39.0	31.0	35
320	...do.....	1.75	1.61	14	43.0	25.0	41
1,024	Springs....	3.55	2.72	11	29.0	7.0	18
512	Broilers...	1.47	1.34	15	63.0	31.0	44
1,088	Springs....	2.28	1.11	13	67.0	11.0	35
768	...do.....	1.58	1.47	14	45.0	30.0	37

In the above work individual records were kept of each battery containing 64 birds. The variation in average weight and in per cent of gains was between batteries of birds fed under the same conditions. The great variation in birds fattened under the same conditions suggests the economical possibility of rejecting certain birds in fattening. A very small per cent of birds called "rangers" were graded out of the receipts at Station 1 and killed without fattening. These birds consisted of black and feather legged stock, Leghorns, and birds out of condition. All black and feather legged birds were kept separate at Station 4 and fed only for a short period during the early part of the feeding season. Much better results could be secured in the fattening stations if only the best birds were selected for fattening, although this would require extra skilled labor for selecting, and involve a different and more complicated system of handling the birds at the packing house.



TYPES OF FEEDERS.

Fig. 1.—A very good feeder. Note the short, thick head. Fig. 2.—A poorer type of feeder. Note crow-like shape of head. Fig. 3.—A "cripple," or bird "off feed."

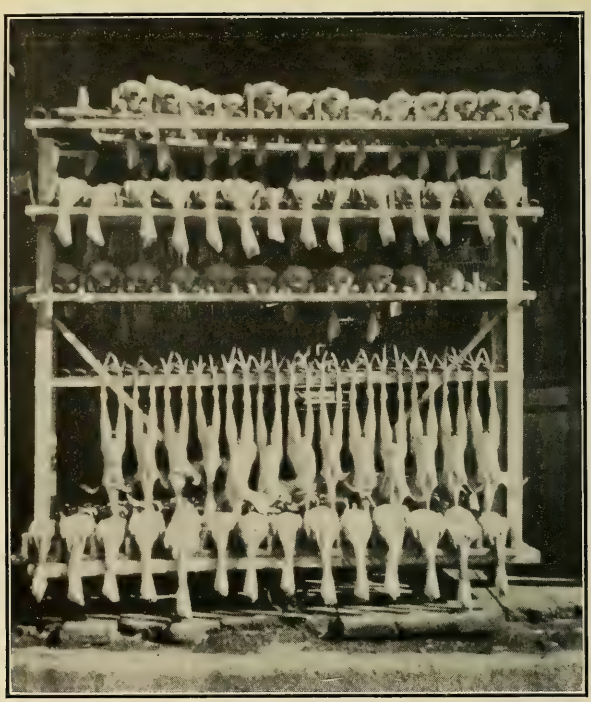


FIG. 1.—RACK FOR SQUATTED AND HANGING DRESSED POULTRY.

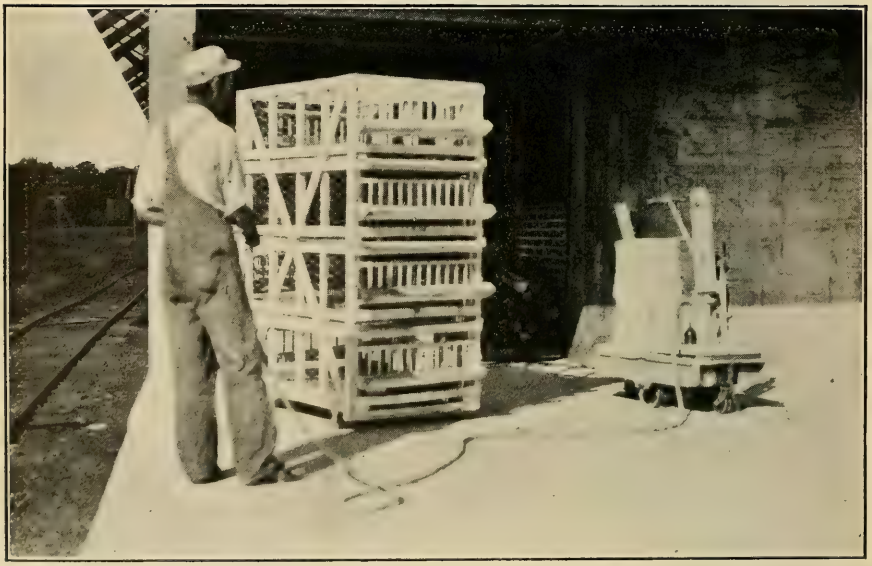


FIG. 2.—SPRAYING MACHINE, A LABOR-SAVING DEVICE.

MIXING MACHINES AND OTHER LABOR-SAVING DEVICES.

The horizontal mixing machine described in Bureau of Animal Industry Bulletin 140 was improved by adding one-third more blades. After this change had been made the feed was mixed more quickly, and the operator could put the dry grain directly into the feeder without previous mixing. Another mixer installed at Station 3 was made on the same plan as the previous machine, except that the blades were arranged as a spiral on the shaft so that in mixing the feed worked toward the center from either end. A mixing machine is a good investment when one is fattening a large number of chickens. The use of labor-saving mechanical devices in fattening stations has enabled one man to care for 4,000 to 5,000 birds. Results secured at these stations show that mechanical features can be used to good advantage in handling poultry commercially, provided the stations are kept clean. Mechanical features, besides saving greatly in the amount of labor, make it possible to use unskilled help in a fattening station. Similar features might be used to good advantage in handling poultry under commercial conditions other than fattening.

ADVANTAGE OF THE PORTABLE FEEDING BATTERY.

On comparing the results in 1911 at Station 1 (Experiment B), where stationary batteries were used, with those secured at the other stations, we find that the average pound of gain was produced with the smallest amount of feed (3.33 pounds) in this experiment, while the lowest cost of gain was made in Experiment C, due largely to the differences in the price of milk. The cost of labor (per pound gain) in Experiment B averaged considerably higher than at any other station. This increased cost was due to the method of handling the chickens, as the stationary feeding battery involves more handling of the birds than the portable feeding battery (described in Bulletin 140); also to the fact that the manager of this feeding station was a higher paid man than the other managers, and to the cost of an extra man employed to go through the batteries daily, or every day during the poor feeding season in October, November, and December, to remove all the birds "off feed" or sickly. The portable feeding battery unquestionably saves labor and eliminates some of the bruising of the birds caused by rehandling where stationary batteries are used.

EXPERT LABOR.

An expert manager, who is paid higher wages than the regular labor about a feeding station, is a necessity in the average feeding station, unless the manager of the packing house understands how to fatten chickens and watches the work closely enough so that he

can successfully direct ordinary help which shows some adaptability in feeding chickens and has had some experience in that work. Under ordinary conditions such help, if well selected and properly advised, may secure very good results; but in case of emergency, such as an over-supply of chickens, or extremely hot or cold weather, the expert manager easily proves his extra worth, as it is impossible for the manager of the average poultry house to always be on hand during such occasions. Conclusions drawn from the season's work show that in these cases the cost of the expert labor, combined with the different methods of handling the birds and the extra labor of picking out sick birds and "cripples," made the labor cost per pound of gain considerably higher than at any of the other stations, the average cost of labor per 100 pounds of gain at the stations being $1.41 at Station 3, $1.58 at Station 2, $1.75 at Station 4, and $2 at Station 1.

GRADING POULTRY.

Two grades of dressed poultry were made at Station 1—fancy, or No. 1, and choice, or No. 2—with a very small per cent of culls which are not included in these tables. The variation at this station for each successive 20 lots was as follows, the figures given representing the No. 2 grade: 7.9 per cent, 13.5 per cent, 13.4 per cent, 14.8 per cent, 14.7 per cent, 12.8 per cent.

Four grades were made at Station 4, classed as Nos. 1, 2, 3, and 4. The No. 1 grade included all fancy dressed poultry which plainly showed the effect of milk feeding, particularly a bleach, which is so characteristic of milk-fed poultry. The second grade was made up of well-bleached poultry, not as well fleshed as the first grade or which had undesirable market features, such as black or feathered legs, dark pin feathers, or not neatly dressed. The third grade included the well-fleshed birds, which were not well bleached, while the fourth grade bore the same relation to the third as the second did the first. The per cent of the several grades was as follows for each successive two weeks during the season: No. 1, 39, 25, 21, 35, 39, 45, and 24; No. 2, 9, 6, 5, 8, 10, 10, and 8; No. 3, 35, 44, 49, 35, 34, 38, and 13; and No. 4, 17, 25, 25, 22, 17, 7, and 55. The per cent of fancy grades varied directly with the per cent of gains in the feeding station, high gains producing a large per cent of the No. 1 grade.

SHRINKAGE IN DRESSING.

The shrinkage in killing and picking without drawing at Station 1 averaged 11.4 per cent for lots 1 to 20; 13.5 per cent for lots 21 to 40; 13.4 per cent for lots 41 to 60; 14.3 per cent for lots 61 to 80; 15.4 per cent for lots 81 to 100; and 15.1 per cent for lots 101 to 113. The lowest shrinkage was in the broilers, and gradually increased with

the size of the chickens as the feeding season advanced. Batteries weighed when received at the poultry house and reweighed the following morning before the birds were fed, gave an average shrink of 2 per cent. The shrinkage in killing and picking without drawing at this station in 1912 averaged 11.3 per cent for lots 1 to 20; 12.4 per cent for lots 21 to 40; 13.4 per cent for lots 41 to 60; 14.1 per cent for lots 61 to 80; and 14.6 per cent for lots 81 to 100. The shrinkage on hens was 12.9 per cent.

INITIAL COST OF CHICKENS AS AFFECTING PROFIT IN FATTENING.

The average cost per pound of the birds into the feeder in Experiment B in 1911 was as follows: Lots 1 to 12, 17.6 cents; lots 13 to 19, 15 cents; lots 20 to 30, 13 cents; lots 31 to 49, 12 cents; lots 50 to 63, 11 cents; lots 64 to 80, 10 cents; lots 81 to 108, 9 cents; and lots 109 to 118, 9.3 cents. The cost of picking, grading, and packing (including freezing) was about 7 cents per head. The gradual decrease of the average cost into the feeder is the reason for feeding longer early in the season, especially as the cheapest gains are made on these first lots; while later the flesh can be bought more cheaply than produced in fattening. For example, an average lot early in the season cost 17.6 cents per pound into the feeder, and the gain in fattening cost 7 cents per pound; an average lot late in the fall costs 9 cents per pound into the feeder, while the gain costs 10.5 cents per pound. The total cost per pound when dressed and packed for this first lot was 20.5 cents; for the other, 13.1 cents; but the first brought a much higher price in the market than the second. These costs were the average extremes of high and low cost, the total dressed costs gradually dropping as the season advanced. The average cost per pound of the birds into the feeding station in Experiment B in 1912 was as follows: Lots 1 to 21, 18 cents; lots 22 to 42, 16 cents; lots 43 to 57, 14.2 cents; lots 58 to 75, 11 cents; lots 76 to 100, 11.2 cents. Average cost per pound for the season 14.05 cents, as compared with 11.5 cents in 1911.

RELATION OF GRAIN FED TO MANURE PRODUCED.

Table 13 shows the average grain consumed and amount of manure produced daily per 100 head of chickens in fattening. This is a record of 900 head of birds at Station 1, Experiment B, kept from July 18 to November 16, 1911. These birds were fed a ration of 1 part shorts, 2 parts low-grade wheat flour, and 3 parts corn meal, by weight, with 6 per cent of tallow, mixed with ordinary buttermilk.

TABLE 13.—*Relative production of poultry droppings and consumption of feed per 100 head.*

Dates.	Average grain daily per 100 head.	Average manure (wet) daily per 100 head.	Per cent of manure to grain.
1911.	*Pounds.*	*Pounds.*	*Per cent.*
July 18–31	12.5	12	96.0
Aug. 1–16	10.9	11	100.9
Aug. 17–31	14.3	11	76.9
Sept. 1–16	13.1	12	91.6
Sept. 17–30	15.4	19	123.4
Oct. 1–16	16.7	20	119.8
Oct. 17–30	16.2	17	104.9
Nov. 1–16	14.5	16	110.3
Average	14.2	14.7	103.5

The figures in the table vary considerably, although it may be stated that the amount of buttermilk in the feed affects the comparisons by increasing the amount of moisture in the droppings, especially during hot weather. The manure when weighed was soft and wet, so that the dry weight would be very much smaller. The birds eat more feed as they increase in size, especially during cool weather.

DIGESTIBLE PROTEIN AND ENERGY VALUES OF THE RATIONS.

The protein and the energy values of the various rations used in these fattening experiments show clearly the effect of thick condensed buttermilk, tallow, and oat flour in fattening. The following prices of grain and milk per 100 pounds were used: Corn meal, $1.35; low-grade wheat flour, $1.35; wheat shorts, $1.28; oat flour, $2.25; condensed buttermilk, $1; and ordinary buttermilk, $0.25. Farmers' Bulletin 346, United States Department of Agriculture, entitled "The Computation of Rations for Farm Animals by the Use of Energy Values," was used in deriving the protein and energy values of these feeds. Sixty per cent of the total feed was estimated as buttermilk in figuring the effect of the buttermilk on the energy value of the feed.

TABLE 14.—*Digestible protein and energy value per 100 pounds of rations used.*

Ration No.	Composition of rations (parts by weight).	Digestible protein.	Energy value.	Cost.
		Pounds.	*Therms.*	
1	3 parts corn meal, 2 parts low-grade wheat flour	8.31	86.41	$1.35
2	3 parts corn meal, 2 parts oat flour (hulls out)	8.36	87.08	1.71
3	3 parts corn meal, 2 parts low-grade wheat flour, 1 part shorts	9.06	84.95	1.34
4	4 parts corn meal, 2 parts low-grade wheat flour, 1 part shorts	8.74	85.50	1.34
5	2 parts corn meal, 1 part oat flour (hulls out), 1 part low-grade wheat flour	8.72	86.22	1.58
	100 pounds ration No. 1, with condensed buttermilk and diluted 1½ parts with water	19.71	117.33	1.95
	100 pounds ration No. 2, with ordinary buttermilk and 6 per cent tallow	14.26	114.59	2.40
	100 pounds ration No. 3, with ordinary buttermilk	14.76	100.41	1.71

Rations Nos. 1, 3, and 4 have a feeding value about equal to ration No. 2 at 36 and 37 cents less per 100 pounds, due largely to the price of oat flour. Ration No. 1 fed with condensed buttermilk diluted with one and one-half parts of water has a much higher feeding value than any of the other rations fed with ordinary buttermilk, at a slightly lower cost than ration No. 2. Rations Nos. 1 and 3 as fed proved in feeding to be the most economical rations, while ration No. 4 gave very good results in cool weather, late in the feeding season.

TABLE 15.—*Comparison of the different rations on the basis of the cost per pound of gain.*

Ration No.	Gain.	Grain.		Buttermilk.		Total cost.
		Amount.	Cost.	Amount.	Cost.	
	Pound.	*Pounds.*		*Pounds.*		
1	1	3.63	$0.049	[1] 2.72	$0.0272	$0.0762
2	1	3.33	.0676	4.99	.0125	.0801
3	1	4.17	.0559	6.27	.0157	.0716
1a	1	4.20	.0567	[1] 2.52	.0252	.0819

[1] Condensed.

Ration No. 1 was fed with condensed buttermilk diluted with 1 part of water, Nos. 2 and 3 were mixed with ordinary buttermilk, and No. 1a is ration No. 1 fed with condensed buttermilk diluted with one and one-half parts of water. Ration No. 2 was fed with 6 per cent of tallow. These costs are figured on a uniform price of milk and grains at all of the stations, while the costs of gains in each experiment is the actual cost at each feeding station, where the price of buttermilk and grain varied. The amount and cost of the grain and buttermilk per pound of gain at each of the feeding stations is given in Table 16.

COMPARISON OF EXPERIMENTS OF 1910, 1911, AND 1912.

Table 16 gives the average results of the feeding experiments covering three years at the four feeding stations, during which time 1,196,646 birds were fed. The lots in Experiment A were fed longer in 1911 than in 1910, which explains the increased cost of the gains during 1911. The ration in Experiment B was cheaper in 1911 than in 1910; the feeding station was run at full capacity during 1911, which reduced the labor cost compared with 1910, when the station was not full. The milk used in Experiment C was much cheaper than that in Experiment B, which lowered the cost of gains in Experiment C. The price of the grains was higher in 1912 than in 1911, especially in Experiments C and D, which increased the cost of gain. Feather picking resulted in much loss of gain in Experiments A, C, and D. The results secured in Experiment C were better, while those in Experiments A and D were not as good as those produced in 1911.

TABLE 16.—*Comparative data of feeding experiments of 1910, 1911, and 1912.*

Experiment.	Year.	Number of head.	Average weight.	Average per cent of gain.	Average grain per pound of gain.	Average cost of feed per pound of gain.	Average cost of labor per pound of gain.	Average total cost per pound of gain.
			Pounds.	*Per cent.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
A	1910	43,944	2.42	18.1	3.26	6.45	1.40	7.85
	1911	60,144	2.47	18.6	3.62	7.83	1.35	9.18
	1912	90,069	2.44	18.6	4.42	8.74	1.63	10.37
B	1910	61,706	2.82	18.7	3.26	7.74	2.59	10.33
	1911	102,684	2.56	26.0	3.33	7.20	2.00	9.20
	1912	90,000	2.36	26.7	3.58	7.70	1.99	9.69
C	1910	113,217		20.2				
	1911	117,151	2.48	20.4	4.45	7.15	1.81	8.96
	1912	211,560	2.21	20.7	3.72	6.61	1.37	7.98
D	1910	89,319		20.1				
	1911	109,800	2.68	18.0	4.18	8.71	1.56	10.27
	1912	107,052	2.69	15.7	4.98	9.95	1.59	11.54

CONCLUSIONS.

The average cost and the amount of feed consumed in fattening 394,744 chickens at the four feeding experiments in alphabetical order during the season of 1911 were, respectively, as follows: Grain per pound of gain, 3.62, 3.33, 4.45, and 4.18 pounds; cost of feed per pound of gain, 7.83, 7.20, 7.15, and 8.71 cents; total cost per pound of gain, 9.18, 9.20, 8.96, and 10.27 cents. The averages in 1912 for 498,681 chickens were: Grain per pound of gain, 4.42, 3.58, 3.72, and 4.98 pounds; cost of feed per pound of gain, 8.74, 7.70, 6.61, and 9.95 cents; total cost per pound of gain, 10.37, 9.69, 7.98, and 11.54 cents.

Tallow, while making the fat on the birds more pronounced, increased the cost of gains. Thick condensed buttermilk in place of tallow produced better results.

Oat flour produced greater gains than low-grade wheat flour, but the latter feed produced cheaper gains.

Beef scraps added to the buttermilk in a fattening ration did not increase the gain. The addition of condimental feeds did not increase the appetite of the birds or help the gains. Grit is of no value in fattening for any period under 15 days.

Under commercial conditions in the Middle West the best results are secured by fattening for about 14 days until the middle of September, and then gradually shortening the period to 6 or 7 days.

The birds ate more feed on three feeds a day but used feed more efficiently when fed only twice.

Mechanical labor-saving devices reduced the cost of fattening by reducing both the total amount of labor and the proportion of skilled labor required. The portable feeding battery turned out the birds in better condition and reduced the cost of labor per pound of gain.

Gains were produced at 1.89 and 1.41 cents, respectively, per pound cheaper in 1911, and 6.30 and 2.68 cents less in 1912 on broilers than on roasters, in two experiments.

There was great variation in the results secured in fattening. This was due to the difference in the ability of the birds to take on flesh, to their weight, and to the effect of weather conditions. The variation in birds makes their selection in fattening of considerable importance, if the labor of the extra work can be handled economically. The influence of the weather in fattening allows a chance of error in comparing fattening experiments conducted at different times.

The bleach produced by fattening with buttermilk varies according to the amount of milk solids consumed by the birds.

The average cost of fattening hens in November and December was 10.92 and 8.74 cents in 1911 and 10.83 and 10.43 cents in 1912, respectively, per pound of gain at two stations. This is higher than the average cost of fattening chickens for the entire season at the same stations but less than the cost of fattening chickens in November and December. Hens cost 7.7 cents per pound in 1911 and 10.3 cents in 1912, into the feeder, so that their flesh can be bought cheaper than produced at this time of the year. Cheaper gains were secured in fattening hens in 1911 on the rations used in fattening chickens than on a ration of corn chop with 15 per cent of shorts mixed with buttermilk.

Chickens cost 17.6 cents per pound into the feeder in July, 1911, while the gains cost 7 cents per pound at this time; in November, 1911, they cost 9 cents per pound into the feeder, and the gains cost 10.5 cents per pound. This influences the profit in fattening and the best length of time to fatten, making it advisable to feed longer in the first part of the season. The cost of picking, grading, and packing (including freezing) was about 7 cents per head, making the total average cost of a pound of dressed poultry in July, 20.5 cents, which gradually decreased through the season to 13.1 cents in November, 1911.

The best results were secured with the following three rations: No. 1, 3 parts of corn meal, 2 parts of low-grade wheat flour, and 1 part of shorts; No. 2, 3 parts of corn meal and 2 parts of low-grade wheat flour, and No. 3, 5 parts of corn meal, 3 parts of low-grade wheat flour, 1 part of shorts, and 5 per cent of tallow. The same feeding value is secured in a ration of 3 parts of corn meal and 2 parts of oat flour but at an increased cost of 37 cents per 100 pounds of gain. Four parts of corn meal, 2 of low-grade wheat flour, and 1 of shorts gave very good results during the latter part of the feeding season, or in cool weather; that is, the proportion of corn meal and low-grade wheat flour may be increased in cool weather.

APPENDIX.

Details of feeding experiments in 1911 and 1912.

EXPERIMENT A, STATION 3, 1911.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1911.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
1	Broilers	1,430	1,913	1.3	July 27 to July 31	11	1,916	2,409	496	26	35	20	3.86	7.87	1.52	9.39
2	do	560	714	1.3	July 23 to July 31	9	633	926	212	30	38	5	2.99	6.08	1.09	7.17
3	do	1,280	2,142	1.7	July 26 to Aug. 3	9	1,510	2,531	389	18	30	8	3.88	7.67	1.38	9.05
4	do	640	1,116	1.7	July 27 to Aug. 4	9	755	1,316	200	18	31	2	3.78	7.59	1.44	9.03
5	do	1,120	1,894	1.7	July 28 to Aug. 6	10	1,456	2,392	498	26	45	5	2.92	5.89	1.22	7.11
6	Springers	720	1,289	1.8	July 29 to Aug. 7	10	929	1,533	244	19	34	6	3.81	7.67	1.65	9.32
7	Broilers	960	1,660	1.7	July 30 to Aug. 7	9	1,114	2,018	358	22	37	7	3.11	6.27	1.39	7.66
8	do	640	958	1.5	July 31 to Aug. 10	11	832	1,174	216	23	34	9	3.85	8.15	2.01	10.16
9	Springers	800	1,398	1.8	Aug. 2 to Aug. 10	9	824	1,683	294	21	37	2	2.80	6.01	1.58	7.59
10	Broilers	560	905	1.6	Aug. 3 to Aug. 11	9	560	1,089	184	20	33	3	3.04	6.79	1.86	8.65
11	Springers	720	1,364	1.9	Aug. 4 to Aug. 13	10	792	1,504	140	10	19	11	5.66	13.01	3.65	16.66
12	do	640	1,194	1.9	Aug. 6 to Aug. 13	8	550	1,373	179	15	28	4	3.07	7.15	2.04	9.19
13	do	639	1,137	1.8	Aug. 8 to Aug. 15	8	543	1,322	185	16	29	2	2.94	7.15	2.18	9.33
14	do	556	1,051	1.9	Aug. 9 to Aug. 17	9	523	1,203	152	14	27	9	3.44	8.63	2.60	11.23
15	do	480	954	2.0	Aug. 12 to Aug. 20	9	499	1,142	188	20	39	2	2.65	6.61	1.76	8.37
16	do	800	1,522	1.9	Aug. 6 to Aug. 24	9	960	1,920	398	26	50	5	2.41	5.93	1.27	7.20
17	do	640	1,268	2.0	Aug. 17 to Aug. 27	11	1,005	1,616	348	27	54	3	2.89	6.91	1.43	8.34
18	do	560	1,056	1.9	Aug. 18 to Aug. 28	11	924	1,402	346	33	62	1	2.67	6.25	1.29	7.54
19	do	400	835	2.1	Aug. 22 to Aug. 31	10	664	1,035	200	24	50	3	3.32	7.40	1.52	8.92
20	do	560	1,110	2.0	Aug. 23 to Sept. 1	10	924	1,407	297	27	53	4	3.11	6.92	1.47	8.39
21	do	640	1,342	2.1	Aug. 26 to Sept. 4	10	1,056	1,638	296	22	46	.....	3.57	7.50	1.53	9.03
22	do	560	1,195	2.1	Aug. 27 to Sept. 5	10	930	1,490	295	25	53	.....	3.15	6.47	1.35	7.82
23	do	640	1,411	2.2	Aug. 31 to Sept. 12	13	1,344	1,783	372	26	58	.....	3.61	7.14	1.39	8.53
24	do	640	1,417	2.2	Sept. 3 to Sept. 13	11	1,133	1,800	383	27	60	.....	2.96	5.68	1.10	6.78
25	do	1,040	2,181	2.1	Sept. 6 to Sept. 15	10	1,602	2,705	524	24	50	6	3.06	5.94	1.21	7.15
26	do	720	1,574	2.2	Sept. 7 to Sept. 16	10	1,102	1,953	379	24	53	4	2.91	5.66	1.10	6.76
27	do	1,520	2,715	1.8	Sept. 8 to Sept. 18	11	2,538	3,333	618	23	41	17	4.11	7.77	1.52	9.29
28	do	720	1,592	2.2	Sept. 9 to Sept. 18	10	1,066	1,879	287	18	40	8	3.71	7.02	1.38	8.40
29	do	1,360	2,893	2.1	Sept. 10 to Sept. 19	10	2,067	3,489	596	21	44	13	3.47	6.53	1.28	7.81
30	do	640	1,338	2.1	Sept. 12 to Sept. 24	13	1,350	1,622	284	21	44	4	4.75	8.83	1.60	10.43

31	...do.....	720	1,631	2.3	Sept. 13 to Sept. 24...	12	1,411	1,924	293	18	41	6	4.82	8.99	1.62	10.61
32	...do.....	1,440	3,722	2.6	Sept. 15 to Sept. 26...	12	2,952	4,341	619	17	43	5	4.77	8.77	1.49	10.26
33	...do.....	1,600	3,739	2.3	Sept. 16 to Sept. 26...	11	3,024	4,469	730	20	46	24	4.14	7.65	1.27	8.92
34	...do.....	880	1,906	2.2	Sept. 17 to Sept. 28...	12	1,848	2,260	354	19	40	11	5.22	9.45	1.62	11.07
35	...do.....	720	1,790	2.5	Sept. 20 to Sept. 28...	9	1,152	2,043	253	14	35	4	4.55	8.14	1.37	9.51
36	...do.....	768	1,757	2.3	Sept. 22 to Sept. 28..	7	945	2,014	257	15	33	10	3.68	1.11	6.51	7.62
37	...do.....	640	1,851	2.9	Sept. 23 to Oct. 1....	9	1,011	2,157	306	17	48	2	3.30	1.09	5.71	6.80
38	...do.....	576	1,584	2.8	Sept. 24 to Oct. 1....	8	795	1,839	253	16	44	2	3.12	1.06	5.40	6.46
39	...do.....	644	1,792	2.8	Sept. 28 to Oct. 3....	6	689	2,109	317	18	49	0	2.17	.77	3.82	4.59
40	...do.....	1,320	3,741	2.8	Oct. 1 to Oct. 10.....	10	2,495	4,528	787	21	60	16	3.17	1.02	6.74	7.76
41	...do.....	640	1,810	2.8	Oct. 3 to Oct. 10.....	8	979	2,154	344	19	54	4	2.85	.91	6.34	7.25
42	...do.....	960	2,766	2.9	Oct. 4 to Oct. 11.....	8	1,450	3,294	528	19	55	4	2.75	.91	6.24	7.15
43	...do.....	832	2,434	2.9	Oct. 6 to Oct. 12.....	7	1,107	2,815	381	16	46	1	2.91	1.01	6.68	7.69
44	Broilers...	501	852	1.7	Oct. 1 to Oct. 15.....	15	1,388	1,205	353	41	70	10	3.93	1.38	8.66	10.04
45	...do.....	240	379	1.6	Oct. 5 to Oct. 18.....	14	622	550	171	45	71	0	3.64	1.33	8.48	9.81
46	...do.....	480	731	1.5	Oct. 6 to Oct. 22.....	17	1,498	1,021	290	40	60	7	5.16	1.80	12.13	13.93
47	Roasters..	960	2,862	3.0	Oct. 7 to Oct. 13.....	7	1,258	3,328	466	16	49	7	2.70	.99	6.24	7.23
48	...do.....	1,280	3,860	3.0	Oct. 8 to Oct. 17.....	10	2,342	4,464	604	16	47	7	3.88	1.46	9.16	10.62
49	Broilers...	320	473	1.5	Oct. 8 to Oct. 23.....	16	934	675	202	43	63	5	4.62	1.63	12.40	14.03
50	Roasters..	960	2,760	2.9	Oct. 11 to Oct. 19....	9	1,565	3,326	566	21	59	4	2.77	1.05	6.95	8.00
51	Broilers...	240	394	1.6	Oct. 11 to Oct. 24....	14	612	546	152	39	63	2	4.03	1.41	9.55	10.96
52	Roasters..	768	2,330	3.0	Oct. 12 to Oct. 20....	9	1,236	2,662	332	14	43	4	3.72	1.39	8.91	10.30
53	...do.....	768	2,365	3.1	Oct. 13 to Oct. 20....	8	1,091	2,666	301	13	39	6	3.62	1.35	8.70	10.05
54	...do.....	768	2,419	3.2	Oct. 14 to Oct. 22....	9	1,244	2,962	543	23	71	0	2.29	.78	5.49	6.27
55	...do.....	961	3,321	3.5	Oct. 15 to Oct. 23....	9	1,586	3,992	671	20	70	0	2.36	.77	5.64	6.41
56	...do.....	1,280	4,094	3.2	Oct. 18 to Oct. 24....	7	1,651	4,466	372	9	29	0	4.44	1.38	10.39	11.77
57	Broilers...	556	872	1.6	Oct. 18 to Oct. 31....	14	1,434	1,088	216	25	39	29	6.64	2.11	15.50	17.61
58	Roasters..	837	2,680	3.2	Oct. 19 to Oct. 25....	7	1,080	2,986	306	11	37	0	3.53	1.04	8.26	9.30
59	Broilers...	336	528	1.6	Oct. 20 to Nov. 2....	14	870	710	182	34	54	11	4.78	1.55	11.17	12.72
60	Roasters..	2,120	6,643	3.1	Oct. 20 to Oct. 26....	7	2,756	7,627	984	15	46	12	2.80	.82	6.51	7.33
61	...do.....	640	1,975	3.1	Oct. 21 to Oct. 29....	9	1,107	2,250	275	14	43	1	4.03	1.23	9.29	10.52
62	...do.....	1,840	5,488	3.0	Oct. 22 to Oct. 29....	8	2,815	6,063	575	10	31	22	4.90	1.50	11.23	12.73
63	Broilers...	290	513	1.8	Oct. 22 to Nov. 6....	16	879	672	159	31	55	2	5.53	1.84	12.87	14.71
64	Roasters..	1,470	4,596	3.1	Oct. 24 to Oct. 30....	7	1,940	5,219	623	14	42	38	3.11	1.01	7.17	8.18
65	...do.....	1,020	3,259	3.2	Oct. 25 to Oct. 31....	7	1,316	3,538	279	9	27	26	4.72	1.53	10.93	12.46
66	...do.....	1,170	3,725	3.2	Oct. 26 to Nov. 1....	7	1,509	4,100	375	10	32	22	4.02	1.41	9.39	10.80
67	...do.....	748	2,315	3.1	Oct. 28 to Nov. 2....	6	808	2,489	174	8	23	16	4.64	1.72	10.96	12.68
68	...do.....	832	2,770	3.3	Oct. 29 to Nov. 6....	9	1,414	3,201	431	16	52	5	3.28	1.16	7.70	8.86
69	...do.....	1,280	4,301	3.4	Nov. 1 to Nov. 7....	7	1,766	4,744	443	10	35	18	3.99	1.39	9.45	10.84
70	...do.....	704	2,251	3.2	Nov. 4 to Nov. 9....	6	817	2,529	278	12	39	3	2.94	.99	6.84	7.83
71	...do.....	1,850	6,116	3.3	Nov. 5 to Nov. 11...	7	2,442	6,919	803	13	43	0	3.04	1.04	7.14	8.18

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT A, STATION 3, 1912.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1912.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
1	Broilers	720	1,191	1.52	Aug. 6 to Aug. 19	14	1,339	1,600	409	34	57	.....	3.27	6.50	1.09	7.69
2	Springers	560	1,014	1.81	Aug. 8 to Aug. 20	13	963	1,230	216	21	39	18	4.46	8.84	1.53	10.37
3	do	720	1,309	1.82	Aug. 9 to Aug. 21	13	1,238	1,600	291	22	40	.....	4.25	8.39	1.48	9.87
4	Broilers	720	1,261	1.75	Aug. 13 to Aug. 22	10	950	1,619	358	28	50	.....	2.65	5.09	1.03	6.12
5	Springers	1,120	2,052	1.81	Aug. 15 to Aug. 23	9	1,366	2,344	312	15	28	.....	4.38	8.22	1.65	9.87
6	Broilers	1,200	2,044	1.70	Aug. 17 to Aug. 25	9	1,392	2,460	416	20	35	8	3.35	6.40	1.36	7.76
7	Springers	2,480	4,465	1.80	Aug. 16 to Aug. 26	11	3,447	5,116	651	15	26	18	5.29	10.06	2.13	12.19
8	Broilers	720	1,189	1.65	Aug. 18 to Aug. 27	10	871	1,438	249	21	35	7	3.50	6.77	1.47	8.24
9	Springers	1,040	1,849	1.78	Aug. 19 to Aug. 27	9	1,123	2,202	353	19	34	13	3.18	6.25	1.39	7.64
10	do	720	1,374	1.91	Aug. 20 to Aug. 28	9	770	1,583	209	15	29	15	3.68	7.23	1.72	8.95
11	Broilers	1,520	2,440	1.61	Aug. 23 to Sept. 2	11	2,098	2,869	429	18	28	11	4.89	9.35	2.30	11.65
12	do	2,240	3,690	1.65	Aug. 23 to Sept. 3	12	3,360	4,632	942	26	42	19	3.57	6.82	1.66	8.48
13	do	1,440	2,446	1.70	Aug. 23 to Sept. 4	13	2,318	3,145	699	29	49	18	3.32	6.39	1.59	7.98
14	Springers	1,360	2,417	1.78	Aug. 26 to Sept. 5	11	1,809	3,031	614	25	45	10	2.95	5.76	1.48	7.24
15	do	720	1,409	1.96	Aug. 28 to Sept. 8	12	1,087	1,749	340	24	47	7	3.20	6.35	1.50	7.85
16	do	1,040	1,835	1.76	Aug. 29 to Sept. 8	11	1,446	2,258	423	41	41	.....	3.42	6.81	1.57	8.38
17	do	960	1,783	1.86	Aug. 30 to Sept. 10	12	1,469	2,168	385	40	40	2	3.82	7.56	1.70	9.26
18	do	800	1,656	2.07	Aug. 31 to Sept. 10	11	1,104	1,938	282	17	35	3	3.92	7.80	1.76	9.56
19	do	880	1,763	2.00	Sept. 3 to Sept. 12	10	1,100	2,077	314	18	36	8	3.50	7.17	1.54	8.71
20	do	1,600	3,028	1.89	Sept. 4 to Sept. 15	12	2,528	3,797	769	25	48	12	3.29	6.72	1.48	8.20
21	do	720	1,507	2.09	Sept. 5 to Sept. 17	13	1,296	1,979	472	31	66	5	2.75	5.67	1.17	6.84
22	do	720	1,599	2.22	Sept. 7 to Sept. 19	13	1,382	2,047	448	28	62	7	3.08	6.32	1.27	7.59
23	do	556	1,162	2.09	Sept. 6 to Sept. 19	14	1,134	1,543	381	33	69	2	2.98	6.06	1.24	7.30
24	do	800	1,639	2.05	Sept. 10 to Sept. 20	11	1,360	2,112	473	29	59	.....	2.88	5.85	1.15	7.00
25	do	1,360	2,635	1.94	Sept. 11 to Sept. 22	12	2,598	3,462	827	31	61	24	3.14	6.41	1.20	7.61
26	do	1,120	2,275	2.03	Sept. 12 to Sept. 23	12	2,139	2,816	541	24	48	27	3.95	8.14	1.53	9.67
27	Broilers	800	1,402	1.75	Sept. 13 to Sept. 23	11	1,400	1,730	328	23	41	24	4.27	8.76	1.66	10.42
28	Springers	1,040	2,161	2.08	Sept. 14 to Sept. 24	11	1,830	2,787	626	29	60	21	2.92	6.08	1.10	7.18
29	do	720	1,547	2.15	Sept. 14 to Sept. 25	12	1,382	1,992	445	29	62	12	3.11	6.39	1.16	7.55
30	do	720	1,588	2.21	Sept. 16 to Sept. 25	10	1,145	1,904	316	20	44	4	3.62	7.50	1.35	8.85

31	...do.....	1,280	2,797	2.19	Sept. 17 to Sept. 26..	10	2,022	3,466	669	24	52	10	3.02	6.24	1.09	7.33
32	...do.....	800	1,771	2.21	Sept. 18 to Sept. 29..	12	1,560	2,254	483	27	60	10	3.23	6.56	1.11	7.67
33	...do.....	1,360	2,774	2.04	Sept. 20 to Sept. 30..	11	2,434	3,577	803	29	59	23	3.03	6.10	1.02	7.12
34	...do.....	930	2,322	2.50	Sept. 23 to Oct. 1....	9	1,358	2,697	375	16	40	.....	3.62	7.32	1.24	8.56
35	...do.....	1,280	2,905	2.27	Sept. 21 to Oct. 1....	11	2,304	3,743	838	29	66	4	2.75	5.56	.92	6.48
36	...do.....	720	1,479	2.05	Sept. 19 to Oct. 2....	14	1,649	1,986	507	34	70	8	3.25	6.58	1.09	7.67
37	...do.....	1,040	2,168	2.08	Sept. 24 to Oct. 2....	9	1,550	2,669	501	23	48	.....	3.09	6.14	1.02	7.16
38	...do.....	1,280	2,790	2.18	Sept. 24 to Oct. 3....	10	2,074	3,318	528	19	41	19	3.93	7.83	1.28	9.11
39	...do.....	960	2,267	2.36	Sept. 25 to Oct. 3....	9	1,421	2,541	274	12	29	14	5.18	10.27	1.68	11.95
40	...do.....	720	1,737	2.41	Sept. 25 to Oct. 4....	10	1,166	2,106	369	21	51	14	3.16	6.26	1.01	7.27
41	...do.....	1,200	2,491	2.08	Sept. 27 to Oct. 6....	10	1,956	2,986	495	20	41	6	3.95	7.71	1.19	8.90
42	...do.....	1,360	3,124	2.30	Sept. 28 to Oct. 7....	10	2,203	3,820	696	22	51	10	3.17	6.19	.92	7.11
43	...do.....	1,360	3,513	2.58	Sept. 30 to Oct. 8....	12	1,904	3,987	474	13	35	12	4.02	7.89	1.23	9.12
44	...do.....	720	1,855	2.58	Oct. 1 to Oct. 8.....	8	893	2,067	212	12	29	6	4.21	8.25	1.29	9.54
45	...do.....	321	724	2.26	Sept. 19 to Oct. 9....	21	1,072	975	251	35	78	4	4.27	8.51	1.39	9.90
46	...do.....	1,280	3,144	2.46	Oct. 1 to Oct. 9.....	9	1,766	3,527	383	12	30	13	4.61	9.02	1.44	10.46
47	...do.....	1,280	3,032	2.37	Oct. 3 to Oct. 11.....	9	1,690	3,580	548	18	43	.....	3.08	6.00	.96	6.96
48	...do.....	1,120	2,871	2.56	Oct. 4 to Oct. 13.....	10	1,770	3,412	541	19	48	7	3.27	6.29	.97	7.26
49	Springers.	2,240	5,249	2.34	Oct. 5 to Oct. 14.....	10	3,651	6,579	1,330	25	59	25	2.75	5.27	.84	6.11
50	...do.....	880	2,212	2.51	Oct. 7 to Oct. 15.....	9	1,338	2,655	443	20	50	2	3.02	5.82	.99	6.81
51	...do.....	1,600	4,020	2.51	Oct. 8 to Oct. 16.....	9	2,496	4,617	597	15	37	8	5.18	8.04	1.42	9.46
52	...do.....	800	2,070	2.59	Oct. 9 to Oct. 16.....	8	1,120	2,396	326	16	41	13	3.44	6.63	1.15	7.78
53	...do.....	1,280	3,521	2.75	Oct. 11 to Oct. 17.....	7	1,715	4,048	527	15	41	7	3.25	6.22	1.09	7.31
54	...do.....	640	1,531	2.39	Oct. 12 to Oct. 20....	9	1,114	1,867	336	22	53	4	3.32	6.42	1.10	7.52
55	...do.....	1,440	3,895	2.71	Oct. 13 to Oct. 21....	9	2,506	4,466	571	15	40	9	4.39	8.52	1.49	10.01
56	...do.....	880	2,309	2.62	Oct. 15 to Oct. 21....	7	1,197	2,692	383	17	44	9	3.13	6.09	1.06	7.15
57	...do.....	800	2,225	2.78	Oct. 16 to Oct. 24....	9	1,408	2,720	495	22	62	.....	2.84	5.45	.95	6.40
58	...do.....	1,680	4,735	2.82	Oct. 16 to Oct. 25....	10	3,293	5,440	705	15	42	.....	4.67	8.96	1.55	10.51
59	...do.....	2,720	7,840	2.88	Oct. 17 to Oct. 27....	11	5,739	8,850	1,010	13	37	65	5.68	10.93	1.80	12.73
60	Roasters..	1,360	4,138	3.04	Oct. 18 to Oct. 28....	11	2,842	4,676	538	13	40	41	5.28	10.19	1.67	11.86
61	...do.....	720	2,204	3.06	Oct. 19 to Oct. 28....	10	1,382	2,518	314	14	44	12	4.40	8.46	1.33	9.79
62	...do.....	1,120	3,460	3.09	Oct. 20 to Oct. 30....	11	2,352	3,988	528	15	47	27	4.45	8.51	1.34	9.85
63	...do.....	880	2,755	3.13	Oct. 21 to Nov. 1....	9	1,514	3,148	393	14	45	11	3.85	7.46	1.17	8.63
64	...do.....	560	1,739	3.11	Oct. 23 to Nov. 1....	10	1,070	1,968	229	13	41	9	4.67	9.05	1.42	10.47
65	...do.....	800	2,636	3.30	Oct. 25 to Nov. 3....	10	1,480	2,858	222	8	28	16	6.67	12.94	2.13	15.07
66	Broilers...	480	916	1.91	Oct. 21 to Nov. 3....	14	1,272	1,187	271	30	56	9	4.69	9.01	1.52	10.53
67	Roasters..	480	1,446	3.01	Oct. 26 to Nov. 4....	10	893	1,596	150	10	31	7	5.95	11.49	1.99	13.48
68	...do.....	960	3,082	3.21	Oct. 26 to Nov. 4....	10	1,786	3,438	356	12	37	13	5.02	9.68	1.67	11.35
69	Broilers...	436	773	1.77	Oct. 24 to Nov. 6....	14	1,147	1,055	282	37	65	24	4.07	7.87	1.41	9.28
70	Roasters..	1,360	4,348	3.20	Oct. 30 to Nov. 7....	9	2,244	4,621	273	6	20	15	8.22	15.94	3.14	19.08
71	...do.....	800	2,578	3.22	Oct. 31 to Nov. 10...	11	1,624	2,741	163	6	20	19	9.96	19.29	3.78	23.07
72	Broilers...	288	489	1.70	Oct. 30 to Nov. 12...	14	743	657	168	34	58	3	4.42	8.63	1.61	10.24
73	Roasters..	800	2,533	3.17	Nov. 3 to Nov. 12...	10	1,464	2,780	247	10	31	8	5.93	11.50	2.23	13.73
74	...do.....	1,280	4,259	3.33	Nov. 6 to Nov. 14...	9	2,061	4,487	228	5	18	40	9.04	17.46	3.43	20.89
75	...do.....	1,040	3,705	3.56	Nov. 7 to Nov. 14...	8	1,498	3,889	184	5	18	10	8.14	15.77	3.11	18.88

Details of feeding experiments in 1911 and 191 2—Continued.

EXPERIMENT A, STATION 3, 1912—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1912.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
76	Roasters..	640	2,224	3.48	Nov. 9 to Nov. 15...	7	800	2,332	108	5	17	.....	7.40	14.29	2.79	17.08
77	...do.....	1,520	4,923	3.24	Nov. 10 to Nov. 17...	8	2,341	5,236	313	6	21	.....	7.48	14.13	2.67	16.80
78	...do.....	720	2,403	3.34	Nov. 12 to Nov. 18...	7	979	2,496	293	4	13	4	10.53	19.35	4.02	23.37
79	...do.....	1,350	4,603	3.38	Nov. 13 to Nov. 19...	7	1,863	5,228	625	14	46	18	2.98	5.42	1.13	6.55
80	...do.....	576	2,044	3.55	Nov. 14 to Nov. 20...	7	806	2,183	139	7	24	9	5.80	10.45	2.12	12.57
81	...do.....	748	2,690	3.60	Nov. 16 to Nov. 21...	6	913	2,859	169	6	23	3	5.40	9.60	1.91	11.51
82	Broilers...	288	468	1.63	Nov. 10 to Nov. 24...	15	786	623	155	33	54	9	5.07	9.37	1.82	11.19
83	Roasters..	1,560	5,158	3.31	Nov. 17 to Nov. 24...	8	2,122	5,412	254	5	16	25	8.35	15.05	2.95	18.00
84	...do.....	3,390	10,389	3.06	Nov. 17 to Nov. 25...	9	5,255	11,001	612	6	18	155	8.59	15.51	2.99	18.50
85	...do.....	816	2,839	3.48	Nov. 21 to Nov. 29...	9	1,281	3,038	199	7	24	17	6.44	11.73	2.09	13.82

EXPERIMENT B, STATION 1, 1911.

					1911.											
1	Springers .	900	1,645	1.8	July 15 to July 28...	14	1,566	2,259	614	37	68	5	2.55	4.44	2.00	6.44
2	...do.....	900	1,601	1.8	July 16 to July 30...	15	1,656	2,187	586	37	65	.....	2.83	4.83	1.78	6.61
3	Broilers...	900	1,512	1.7	July 19 to Aug. 1....	14	1,558	2,135	623	41	69	7	2.50	4.38	1.49	5.87
4	...do.....	900	1,565	1.7	July 20 to Aug. 2....	14	1,521	2,171	606	39	67	.....	2.51	4.40	1.41	5.81
5	Springers .	900	1,651	1.8	July 21 to Aug. 3....	14	1,539	2,279	628	38	70	7	2.45	4.39	1.32	5.71
6	...do.....	900	1,696	1.9	July 21 to Aug. 5....	16	1,746	2,167	471	28	52	.....	3.71	6.76	2.07	8.83
7	Broilers...	900	1,472	1.6	July 22 to Aug. 6....	16	1,827	2,174	702	48	78	.....	2.60	4.75	1.39	6.14
8	Springers .	900	1,573	1.8	.....do.....	16	1,755	2,201	628	40	70	10	2.79	5.11	1.51	6.62
9	Broilers...	900	1,370	1.5	July 22 to Aug. 7....	17	1,872	2,010	640	47	71	5	2.93	5.38	1.58	6.96
10	Springers .	900	1,671	1.9	.....do.....	17	1,872	2,270	599	36	67	7	3.13	5.75	1.70	7.45
11	...do.....	900	1,590	1.8	July 23 to Aug. 8....	17	1,919	2,133	543	34	60	8	3.53	6.60	1.96	8.56
12	...do.....	900	1,600	1.8	July 23 to Aug. 8....	17	1,872	2,128	528	33	59	5	3.55	6.29	1.97	8.26
13	Broilers...	900	1,403	1.6	July 25 to Aug. 9....	16	1,859	1,948	545	39	61	29	3.41	6.55	2.02	8.57
14	Springers .	900	1,629	1.8	July 26 to Aug. 10...	16	1,730	2,043	414	25	46	17	4.18	8.28	2.69	10.97
15	...do.....	900	1,729	1.9	July 27 to Aug. 11...	16	1,714	2,199	470	27	52	4	3.65	7.34	2.49	9.83
16	...do.....	900	1,706	1.9	July 29 to Aug. 13...	16	1,629	2,267	561	33	62	.....	2.90	6.01	2.12	8.13
17	...do.....	900	1,750	1.9	July 31 to Aug. 14...	15	1,485	2,237	487	28	54	11	3.05	6.59	2.40	8.99
18	...do.....	900	1,887	2.1	Aug. 2 to Aug. 15...	14	1,368	2,328	441	23	49	14	3.10	6.90	2.53	9.43
19	...do.....	900	1,740	1.9	Aug. 3 to Aug. 16....	14	1,359	2,182	442	25	49	13	3.07	6.99	2.57	9.56
20	...do.....	900	1,867	2.1	Aug. 4 to Aug. 17....	14	1,359	2,274	407	22	45	7	3.34	7.68	2.83	10.51

21	...do.....	900	1,957	2.2	Aug. 5 to Aug. 18....	14	1,350	2,312	355	18	39	.....	3.80	8.90	3.30	12.20
22	...do.....	900	2,027	2.3	Aug. 7 to Aug. 20....	14	1,395	2,422	395	20	44	19	3.53	8.41	2.99	11.40
23	...do.....	900	1,925	2.1	Aug. 8 to Aug. 22....	15	1,539	2,335	410	21	46	8	3.75	9.02	3.15	12.17
24	...do.....	900	1,954	2.2	Aug. 10 to Aug. 22....	13	1,386	2,478	524	27	58	14	2.65	6.32	2.11	8.43
25	...do.....	900	1,880	2.1	Aug. 11 to Aug. 23....	13	1,475	2,399	519	28	58	9	2.84	6.76	2.19	8.95
26	...do.....	900	2,152	2.4	Aug. 12 to Aug. 24....	13	1,467	2,701	549	25	61	7	2.67	6.40	1.91	8.31
27	...do.....	900	1,920	2.1	.....do.....	13	1,467	2,458	538	28	60	14	2.73	6.38	2.01	8.39
28	...do.....	900	1,815	2.0	Aug. 12 to Aug. 25....	14	1,602	2,431	616	34	68	17	2.60	6.19	1.85	8.04
29	...do.....	900	1,975	2.2	Aug. 13 to Aug. 27....	15	1,782	2,576	601	31	67	23	2.96	7.07	1.95	9.02
30	...do.....	900	2,141	2.4	Aug. 13 to Aug. 28....	16	1,908	2,874	733	34	81	15	2.60	6.24	1.71	7.95
31	...do.....	900	1,663	1.9	Aug. 16 to Aug. 29....	14	1,737	2,482	819	49	91	14	2.12	5.07	1.39	6.46
32	...do.....	900	1,837	2.0	Aug. 18 to Aug. 30....	13	1,760	2,713	876	48	97	13	2.01	4.75	1.28	6.03
33	...do.....	900	2,044	2.3	.....do.....	13	1,674	2,661	617	30	69	13	2.71	6.40	1.68	8.08
34	...do.....	900	2,027	2.3	Aug. 18 to Aug. 31....	14	1,818	2,702	675	33	75	15	2.69	6.32	1.67	7.99
35	...do.....	900	2,078	2.3	Aug. 19 to Sept. 1....	14	1,809	2,734	656	32	73	3	2.76	6.42	1.72	8.14
36	...do.....	900	2,005	2.2	Aug. 21 to Sept. 4....	15	1,970	2,827	822	41	91	3	2.40	5.67	1.50	7.17
37	...do.....	900	2,046	2.3	Aug. 24 to Sept. 5....	13	1,856	2,763	717	35	80	9	2.59	5.80	1.51	7.31
38	...do.....	900	2,095	2.3	Aug. 25 to Sept. 5....	12	1,503	2,711	616	29	68	8	2.44	5.70	1.49	7.19
39	...do.....	900	2,094	2.3	Aug. 25 to Sept. 6....	13	1,611	2,821	727	35	31	4	2.22	5.31	1.35	6.66
40	...do.....	900	2,132	2.4	Aug. 25 to Sept. 7....	14	1,728	2,813	681	32	76	18	2.54	5.89	1.51	7.40
41	...do.....	900	2,236	2.5	Aug. 27 to Sept. 8....	13	1,629	2,848	612	27	68	19	2.66	6.07	1.57	7.64
42	...do.....	900	2,069	2.3	Aug. 28 to Sept. 11...	15	1,910	2,765	696	34	77	6	2.74	5.75	1.48	7.23
43	...do.....	900	2,348	2.6	Aug. 30 to Sept. 10...	12	1,567	2,799	451	19	50	10	3.47	7.79	1.98	9.77
44	...do.....	900	2,101	2.3	Aug. 31 to Sept. 11...	12	1,587	2,763	662	31	74	11	2.40	5.71	1.36	7.07
45	...do.....	900	1,938	2.2	Sept. 1 to Sept. 13....	13	1,700	2,584	646	33	72	15	2.63	5.84	1.48	7.32
46	...do.....	900	2,239	2.5	Sept. 2 to Sept. 14....	13	1,575	2,884	645	29	72	14	2.44	5.55	1.36	6.91
47	...do.....	900	2,209	2.5	Sept. 2 to Sept. 15....	14	1,683	2,749	540	24	60	15	3.12	6.87	1.73	8.60
48	...do.....	900	2,058	2.3	Sept. 2 to Sept. 17....	16	1,899	2,798	740	36	82	21	2.57	5.55	1.40	6.95
49	...do.....	900	2,347	2.6	Sept. 3 to Sept. 18....	16	1,908	2,993	646	28	72	33	2.95	6.18	1.57	7.75
50	...do.....	900	2,193	2.4	Sept. 4 to Sept. 18....	15	1,800	2,862	669	30	74	26	2.69	5.83	1.44	7.27
51	...do.....	900	2,171	2.4	Sept. 5 to Sept. 19...	15	1,818	2,796	625	29	69	16	2.91	6.24	1.61	7.85
52	...do.....	900	2,232	2.5	Sept. 5 to Sept. 19...	14	1,701	2,774	542	24	60	22	3.14	6.66	1.71	8.38
53	...do.....	900	2,352	2.6	Sept. 6 to Sept. 20...	14	1,710	2,939	587	25	65	22	2.91	6.18	1.57	7.75
54	...do.....	900	2,235	2.5	Sept. 8 to Sept. 21...	14	1,737	2,900	665	30	74	19	2.61	5.54	1.40	6.94
55	...do.....	900	2,133	2.4	Sept. 9 to Sept. 22...	14	1,773	2,901	768	36	85	18	2.31	4.89	1.21	6.10
56	...do.....	900	2,290	2.5	.....do.....	14	1,773	2,909	619	27	69	24	2.86	6.03	1.51	7.54
57	...do.....	900	2,350	2.6	Sept. 11 to Sept. 24..	14	1,773	2,874	524	22	58	18	3.38	7.21	1.86	9.07
58	...do.....	900	2,315	2.6	Sept. 12 to Sept. 25..	14	1,809	2,834	519	22	58	15	3.49	7.48	1.89	9.37
59	...do.....	900	2,331	2.6	Sept. 13 to Sept. 27..	15	1,998	2,908	577	25	64	15	3.46	7.35	1.84	9.19
60	...do.....	900	2,276	2.5	.....do.....	15	1,998	2,876	600	26	67	20	3.33	7.07	1.77	8.84
61	...do.....	900	2,343	2.6	Sept. 15 to Sept. 28..	14	1,899	3,004	661	28	73	8	2.87	6.11	1.53	7.64
62	...do.....	900	2,473	2.8	Sept. 16 to Sept. 29..	14	1,908	3,001	528	21	59	18	3.61	7.69	1.93	9.62
63	...do.....	900	2,376	2.6	Sept. 18 to Oct. 1....	14	1,953	2,992	616	26	68	15	3.17	6.51	1.68	8.19
64	...do.....	900	2,319	2.6	Sept. 19 to Oct. 2....	14	1,971	3,118	799	34	89	15	2.47	5.16	1.28	6.44
65	...do.....	900	2,218	2.5	Sept. 19 to Oct. 3....	15	2,142	2,977	759	34	84	23	2.82	5.89	1.45	7.34

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT B, STATION 1, 1911—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1911.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
66	Springers	900	2,251	2.5	Sept. 20 to Oct. 4	15	2,124	2,947	696	31	77	27	3.05	6.38	1.67	8.05
67	do	900	2,364	2.6	Sept. 22 to Oct. 5	14	1,989	2,969	605	26	67	14	3.29	6.83	1.69	8.52
68	do	900	2,554	2.8	do	14	1,989	3,059	505	20	56	4	3.94	8.18	2.03	10.21
69	do	900	2,554	2.8	Sept. 23 to Oct. 6	14	1,998	3,165	611	24	68	12	3.27	6.78	1.68	8.46
70	do	900	2,520	2.8	Sept. 24 to Oct. 8	15	2,202	3,164	644	26	72	12	3.42	7.08	1.70	8.78
71	do	900	2,583	2.9	Sept. 25 to Oct. 8	14	2,016	3,291	708	27	79	20	2.85	6.09	1.44	7.53
72	do	900	2,674	3.0	Sept. 27 to Oct. 10	14	2,016	3,331	657	25	73	32	6.07	6.33	1.52	7.85
73	do	900	2,377	2.6	Sept. 26 to Oct. 11	16	2,358	3,049	672	28	75	29	3.51	7.13	1.73	8.86
74	do	900	2,520	2.8	Sept. 20 to Oct. 12	14	2,052	3,393	873	35	97	9	2.35	4.84	1.31	5.97
75	do	900	2,411	2.7	Sept. 30 to Oct. 15	14	2,097	3,309	898	37	100	17	2.34	4.78	1.09	5.87
76	do	900	2,762	3.1	Oct. 1 to Oct. 15	15	2,340	3,554	792	29	88	10	2.95	5.51	1.37	6.88
77	do	900	2,528	2.8	do	15	2,259	3,203	675	27	75	19	3.35	6.83	1.51	8.34
78	do	900	2,616	2.9	Oct. 3 to Oct. 16	14	2,188	3,255	639	24	71	23	3.42	7.08	1.61	8.69
79	do	900	2,819	3.1	Oct. 4 to Oct. 17	14	2,160	3,293	474	17	53	17	4.56	9.38	2.14	11.52
80	do	900	2,766	3.1	do	14	2,106	3,238	472	17	52	20	4.46	9.17	2.09	11.26
81	do	900	2,493	2.8	Oct. 5 to Oct. 18	14	2,151	2,990	497	20	55	18	4.33	8.89	2.00	10.89
82	Roasters	84	422	5.0	Oct. 7 to Oct. 18	12	171	458	36	9	43	0	4.75	9.78	2.19	11.97
83	Springers	900	2,807	3.1	Oct. 7 to Oct. 20	14	2,106	3,411	604	22	67	21	3.49	7.33	1.66	8.99
84	do	900	2,750	3.1	Oct. 9 to Oct. 22	14	2,142	3,314	564	21	63	13	3.80	7.80	1.81	9.61
85	do	900	2,556	2.8	Oct. 10 to Oct. 23	14	2,106	3,319	763	30	85	15	2.76	5.68	1.34	7.02
86	do	900	2,710	3.0	Oct. 11 to Oct. 24	14	2,115	3,265	555	21	62	26	3.81	7.90	1.87	9.77
87	do	900	2,708	3.0	Oct. 12 to Oct. 25	14	2,097	3,332	624	23	69	13	3.36	7.01	1.68	8.69
88	do	900	2,872	3.2	Oct. 13 to Oct. 26	14	2,088	3,398	526	18	58	22	3.97	8.32	2.05	10.37
89	do	900	2,633	2.9	Oct. 14 to Oct. 27	14	2,043	3,405	772	29	86	17	2.65	5.61	1.35	6.96
90	do	900	2,716	3.0	Oct. 15 to Oct. 27	13	1,961	3,323	607	22	67	23	3.23	6.98	1.71	8.69
91	do	900	2,994	3.3	Oct. 17 to Oct. 30	14	2,088	3,569	575	19	64	15	3.63	7.83	1.96	9.79
92	do	900	2,973	3.3	Oct. 18 to Oct. 31	14	2,034	3,507	534	18	59	13	3.81	8.87	2.32	11.19
93	do	900	2,917	3.2	Oct. 19 to Nov. 1	14	2,034	3,359	442	15	49	14	4.60	9.95	2.70	12.65
94	do	900	2,815	3.1	Oct. 20 to Nov. 2	14	2,016	3,060	245	9	27	26	8.23	18.00	4.00	22.00
95	do	900	2,966	3.3	Oct. 22 to Nov. 3	13	1,936	3,449	483	16	54	12	4.01	8.96	2.52	11.48
96	do	1,350	4,696	3.5	Oct. 22 to Nov. 6	15	3,119	5,213	517	11	38	38	6.03	13.47	4.04	17.51
97	do	900	2,679	3.0	Oct. 26 to Nov. 7	13	1,764	3,320	641	24	71	8	2.75	6.23	1.92	8.15
98	do	900	3,182	3.5	Oct. 28 to Nov. 8	12	1,647	3,535	353	11	39	11	4.67	10.69	3.05	13.74
99	do	900	2,955	3.3	Oct. 29 to Nov. 9	12	1,638	3,580	625	21	69	7	2.62	5.73	1.79	7.52
100	do	900	2,990	3.3	Oct. 31 to Nov. 10	11	1,458	3,506	516	17	57	4	2.83	6.61	1.98	8.59

101	...do.....	900	3,127	3.5	Nov. 1 to Nov. 12...	12	1,593	3,408	281	9	31	12	5.67	13.45	3.70	17.15
102	...do.....	900	3,131	3.5	Nov. 2 to Nov. 15...	12	1,557	3,594	463	15	51	11	3.36	8.01	2.14	10.15
103	...do.....	900	2,831	3.2	Nov. 3 to Nov. 14...	12	1,566	3,284	453	16	50	7	3.46	8.27	2.26	10.53
104	...do.....	1,800	5,941	3.3	Nov. 4 to Nov. 15...	12	3,096	7,190	1,249	21	69	0	2.47	5.89	1.61	7.50
105	...do.....	900	2,996	3.3	Nov. 5 to Nov. 16...	12	1,530	3,344	348	12	39	10	4.40	10.55	2.95	13.50
106	...do.....	900	3,076	3.4	Nov. 5 to Nov. 17...	13	1,665	3,625	549	18	61	8	3.03	7.30	2.05	9.35
107	...do.....	900	2,964	3.3	Nov. 7 to Nov. 19...	13	1,715	3,452	488	16	54	10	3.51	8.49	2.37	10.86
108	...do.....	900	2,956	3.3	Nov. 8 to Nov. 19...	12	1,521	3,270	314	11	35	8	4.84	11.55	3.32	14.87
109	...do.....	900	3,025	3.4	Nov. 8 to Nov. 20...	13	1,647	3,398	373	12	41	13	4.42	10.52	3.08	13.60
110	...do.....	900	3,151	3.5	Nov. 9 to Nov. 21...	13	1,674	3,400	249	8	28	24	6.72	14.70	4.71	19.41
111	...do.....	900	3,067	3.4	Nov. 10 to Nov. 22...	13	1,674	3,431	364	12	40	16	4.60	10.01	3.31	13.32
112	...do.....	900	3,178	3.5	Nov. 13 to Nov. 23..	11	1,413	3,384	206	7	23	20	6.86	15.94	5.34	21.28
113	...do.....	1,350	4,680	3.5	Nov. 14 to Nov. 23..	10	1,931	5,097	417	9	31	28	4.63	9.31	3.03	12.34

EXPERIMENT B, STATION 1, 1912.

					1912.											
1	Springers .	900	1,510	1.68	July 29 to Aug. 11...	14	1,568	2,187	677	45	75	21	2.32	5.60	2.40	8.00
2	...do.....	900	1,419	1.58	July 31 to Aug. 13...	14	1,532	2,160	741	52	82	8	2.07	5.00	1.65	6.65
3	...do.....	900	1,504	1.67	Aug. 2 to Aug. 14....	13	1,469	2,173	569	51	74	8	2.20	5.31	1.45	6.76
4	...do.....	900	1,517	1.69	Aug. 6 to Aug. 19....	14	1,399	1,984	467	31	52	10	3.00	8.32	2.03	10.35
5	...do.....	900	1,506	1.67	Aug. 8 to Aug. 20....	13	1,338	2,036	530	35	59	.....	2.52	6.11	1.82	7.93
6	...do.....	900	1,688	1.88	Aug. 9 to Aug. 22....	14	1,435	2,331	643	38	71	.....	2.23	5.41	1.62	7.03
7	...do.....	900	1,759	1.95	Aug. 11 to Aug. 25...	14	1,541	2,310	551	31	61	7	2.80	6.77	2.00	8.77
8	...do.....	900	1,711	1.90	Aug. 13 to Aug. 26...	14	1,459	2,206	495	29	55	2	2.95	7.14	2.13	9.27
9	...do.....	900	1,724	1.92	Aug. 14 to Aug. 26...	13	1,376	2,342	618	36	69	6	2.23	5.39	1.60	6.99
10	...do.....	900	1,789	1.99	Aug. 15 to Aug. 27...	13	1,317	2,299	510	29	57	6	2.58	6.24	1.83	8.07
11	...do.....	900	1,720	1.91	Aug. 16 to Aug. 28...	13	1,268	2,184	464	27	52	.....	2.73	5.61	1.96	8.57
12	...do.....	900	1,712	1.90	Aug. 17 to Aug. 29...	13	1,231	2,152	440	26	49	10	2.80	6.77	2.03	8.80
13	...do.....	900	1,627	1.81	Aug. 19 to Aug. 29...	11	1,085	2,187	560	34	62	.....	1.94	4.68	1.44	6.12
14	...do.....	900	1,765	1.85	Aug. 21 to Aug. 30...	10	1,084	2,224	459	26	51	6	2.36	5.71	1.57	7.28
15	...do.....	900	1,729	1.92	.....do.....	10	1,171	2,219	490	28	54	5	2.39	5.78	1.62	7.40
16	...do.....	900	1,771	1.97	Aug. 22 to Sept. 2...	12	1,288	2,318	547	31	61	.....	2.35	5.70	1.48	7.18
17	...do.....	900	1,744	1.94	Aug. 23 to Sept. 3...	12	1,284	2,263	519	30	58	11	2.47	5.98	1.55	7.53
18	...do.....	900	1,730	1.92	Aug. 23 to Sept. 4...	13	1,398	2,342	612	35	68	13	2.28	5.52	1.44	6.96
19	...do.....	900	1,567	1.74	Aug. 24 to Sept. 5...	13	1,402	2,309	742	47	82	5	1.89	4.57	1.18	5.75
20	...do.....	900	1,822	2.02	Aug. 24 to Sept. 6...	14	1,521	2,326	504	28	56	.....	3.02	7.31	1.88	9.19
21	...do.....	900	1,762	1.96	Aug. 26 to Sept. 7...	13	1,379	2,202	440	25	49	33	3.13	7.58	2.13	9.71
22	...do.....	900	1,691	1.88	Aug. 26 to Sept. 9...	15	1,710	2,176	485	29	54	1	3.53	8.11	2.10	10.21
23	...do.....	900	1,559	1.73	Aug. 27 to Sept. 9...	14	1,604	2,244	685	44	76	10	2.34	5.38	1.38	6.76
24	...do.....	900	1,831	2.03	Aug. 28 to Sept. 10..	14	1,607	2,403	572	31	64	17	2.81	6.46	1.65	8.11
25	...do.....	900	1,745	1.94	Aug. 28 to Sept. 11..	15	1,734	2,358	613	35	68	.....	2.83	6.51	1.66	8.17

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT B, STATION 1, 1912—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1912.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
26	Springers	900	1,947	2.16	Aug. 29 to Sept. 12..	15	1,828	2,560	613	32	68	5	2.98	6.86	1.69	8.55
27	...do.....	900	1,826	2.03	Aug. 31 to Sept. 13..	14	1,691	2,477	651	36	72	19	2.60	5.97	1.46	7.43
28	...do.....	900	2,109	2.34	Aug. 31 to Sept. 15..	16	1,980	2,575	466	22	52	10	4.25	9.77	2.28	12.05
29	...do.....	900	1,799	2.00	Aug. 31 to Sept. 16..	17	2,154	2,601	802	45	89	6	2.69	6.18	1.41	7.59
30	...do.....	900	1,987	2.21	Sept. 3 to Sept. 16...	14	1,773	2,592	605	30	67	5	2.93	6.74	1.71	8.45
31	...do.....	900	1,813	2.01	Sept. 4 to Sept. 17...	14	1,829	2,562	749	41	83	11	2.44	5.61	1.28	6.89
32	...do.....	900	1,844	2.05	Sept. 5 to Sept. 18...	14	1,847	2,685	841	46	93	2	2.20	5.05	1.14	6.19
33	...do.....	900	1,887	2.10	Sept. 6 to Sept. 19...	14	1,862	2,579	692	37	77	.....	2.69	6.19	1.39	7.58
34	...do.....	900	2,115	2.35	Sept. 7 to Sept. 19...	13	1,735	2,829	714	34	79	.....	2.43	5.59	1.24	6.83
35	...do.....	900	2,153	2.39	Sept. 8 to Sept. 20...	13	1,796	2,808	655	30	73	4	2.74	6.31	1.34	7.65
36	...do.....	900	2,144	2.38	Sept. 10 to Sept. 22..	13	1,805	2,716	572	27	64	3	3.16	7.26	1.58	8.84
37	...do.....	900	2,068	2.30	Sept. 11 to Sept. 23..	13	1,862	2,833	765	37	85	.....	2.43	5.60	1.18	6.78
38	...do.....	900	2,141	2.38	Sept. 12 to Sept. 24..	13	1,750	2,798	657	31	73	4	2.66	6.13	1.38	7.51
39	...do.....	900	2,130	2.37	Sept. 12 to Sept. 25..	14	2,038	2,875	745	35	83	5	2.74	6.28	1.32	7.60
40	...do.....	900	2,168	2.41	Sept. 13 to Sept. 26..	14	2,055	2,894	726	34	81	10	2.83	6.51	1.35	7.86
41	...do.....	900	2,141	2.38	Sept. 14 to Sept. 27..	14	2,047	2,927	786	37	87	5	2.60	5.99	1.24	7.23
42	...do.....	900	2,374	2.64	Sept. 15 to Sept. 29..	15	2,221	3,004	630	27	70	.....	3.53	8.11	1.66	9.77
43	...do.....	900	2,375	2.64	Sept. 17 to Sept. 30..	14	2,081	3,170	795	33	88	.....	2.62	6.02	1.20	7.22
44	...do.....	900	2,382	2.65	Sept. 17 to Oct. 1....	15	2,215	3,125	743	31	83	.....	2.98	6.86	1.31	8.17
45	...do.....	900	2,322	2.58	Sept. 18 to Oct. 1....	14	2,060	3,031	709	31	79	11	2.91	6.68	1.35	8.03
46	...do.....	900	2,333	2.59	Sept. 19 to Oct. 1....	13	1,918	3,082	749	32	83	4	2.56	5.89	1.18	7.07
47	...do.....	900	2,422	2.69	Sept. 20 to Oct. 6....	17	2,497	3,192	770	32	86	7	3.24	7.46	1.44	8.90
48	...do.....	900	2,188	2.43	Sept. 20 to Oct. 7....	18	2,611	3,026	838	38	93	14	3.12	7.17	1.41	8.58
49	...do.....	900	2,535	2.82	Sept. 21 to Oct. 8....	18	2,788	3,353	818	32	91	17	3.41	7.29	1.44	8.73
50	...do.....	900	2,371	2.63	Sept. 22 to Oct. 9....	18	2,769	3,148	777	33	86	8	3.56	7.62	1.50	9.12
51	...do.....	900	2,254	2.50	Sept. 23 to Oct. 10...	18	2,797	3,060	806	36	90	13	3.47	7.31	1.48	8.79
52	...do.....	900	2,297	2.55	Sept. 25 to Oct. 10...	16	2,448	2,983	686	30	76	4	3.57	7.64	1.52	9.16
53	...do.....	900	2,330	2.59	Sept. 26 to Oct. 11...	16	2,405	3,027	697	30	77	1	3.45	7.44	1.49	8.93
54	...do.....	900	2,387	2.65	Sept. 26 to Oct. 12...	17	2,582	3,044	657	28	73	18	3.93	8.41	1.70	10.11
55	...do.....	900	2,428	2.70	Sept. 28 to Oct. 14...	17	2,601	3,025	597	25	66	14	4.36	9.33	1.80	11.13
56	...do.....	900	2,678	2.98	Sept. 29 to Oct. 14...	16	2,432	3,583	905	34	100	17	2.69	5.75	1.13	6.88
57	...do.....	900	2,653	2.95	Sept. 30 to Oct. 15...	16	2,409	3,226	573	22	64	13	4.20	8.99	1.84	10.83
58	...do.....	900	2,530	2.81	Oct. 1 to Oct. 16.....	16	2,396	3,232	702	28	78	.....	3.41	7.30	1.51	8.81
59	...do.....	900	2,771	3.08	Oct. 3 to Oct. 17.....	15	2,244	3,247	476	17	53	14	4.71	10.09	2.07	12.16
60	...do.....	900	2,383	2.65	Oct. 3 to Oct. 18.....	16	2,386	3,129	746	31	83	23	3.20	6.85	1.42	8.27

61	...do.....	900	2,679	2.98	Oct. 4 to Oct. 20.....	17	2,500	3,375	696	26	77	10	3.59	7.69	1.57	9.26
62	...do.....	900	2,617	2.91	Oct. 8 to Oct. 21.....	14	2,109	3,266	649	25	72	11	3.25	6.95	1.45	8.40
63	...do.....	900	2,440	2.71	Oct. 9 to Oct. 22.....	14	2,122	3,032	592	24	66	7	3.58	7.67	1.63	9.30
64	...do.....	900	2,495	2.77	Oct. 10 to Oct. 28.....	14	2,157	3,239	744	30	83	17	2.90	6.20	1.33	7.53
65	...do.....	900	2,709	3.01	Oct. 11 to Oct. 24.....	14	2,181	3,159	450	17	50	13	4.85	10.37	2.24	12.61
66	...do.....	900	2,675	2.97	Oct. 12 to Oct. 25.....	14	2,200	3,220	545	20	61	18	4.04	8.64	1.89	10.53
67	...do.....	900	2,864	3.18	Oct. 12 to Oct. 27.....	16	2,570	3,408	544	19	60	14	4.72	10.10	2.13	12.23
68	...do.....	900	2,751	3.06	Oct. 13 to Oct. 28.....	16	2,586	3,330	579	21	64	26	4.47	9.56	2.03	11.59
69	...do.....	900	2,905	3.23	Oct. 15 to Oct. 29.....	15	2,362	3,450	545	21	61	35	4.33	9.33	2.14	11.47
70	...do.....	900	2,743	3.05	Oct. 15 to Oct. 30.....	16	2,494	3,299	556	20	62	27	4.49	9.60	2.26	11.86
71	...do.....	900	2,694	2.99	Oct. 16 to Oct. 31.....	16	2,511	3,361	667	25	74	.....	3.76	8.06	1.91	9.97
72	...do.....	900	2,812	3.12	Oct. 17 to Oct. 31.....	15	2,368	3,288	476	17	53	25	4.97	10.64	2.51	13.15
73	...do.....	900	2,824	3.14	Oct. 18 to Nov. 1.....	15	2,361	3,395	571	20	63	19	4.14	8.85	2.13	10.98
74	...do.....	900	2,821	3.13	Oct. 19 to Nov. 3.....	16	2,520	3,448	627	22	70	16	4.02	8.60	2.03	10.63
75	...do.....	900	2,850	3.17	Oct. 19 to Nov. 4.....	17	2,688	3,474	624	22	69	15	4.31	9.21	2.18	11.39
76	...do.....	900	2,920	3.24	Oct. 22 to Nov. 5.....	15	2,376	3,430	510	18	57	25	4.66	9.97	2.47	12.44
77	...do.....	900	2,941	3.27	Oct. 24 to Nov. 6.....	14	2,195	3,504	563	19	63	19	3.90	8.35	2.05	10.40
78	...do.....	900	2,946	3.27	Oct. 26 to Nov. 7.....	13	2,138	3,601	655	22	73	16	3.26	6.56	1.61	8.17
79	...do.....	900	2,858	3.18	Oct. 27 to Nov. 8.....	13	2,125	3,405	547	19	61	38	3.88	7.80	1.91	9.71
80	...do.....	900	2,858	3.18	Oct. 28 to Nov. 10.....	14	2,260	3,485	627	22	70	25	3.60	7.25	1.79	9.04
81	...do.....	900	2,827	3.14	Oct. 28 to Nov. 11.....	15	2,405	3,372	545	19	61	26	4.41	8.86	2.21	11.07
82	...do.....	900	2,818	3.13	Oct. 30 to Nov. 12.....	14	2,206	3,320	502	18	56	24	4.39	8.84	2.17	11.01
83	...do.....	900	2,919	3.24	Oct. 31 to Nov. 13.....	14	2,234	3,410	491	17	55	40	4.55	9.15	2.23	11.38
84	...do.....	900	3,134	3.48	Nov. 1 to Nov. 14.....	14	2,221	3,551	417	13	46	20	5.33	10.71	2.53	13.24
85	...do.....	900	3,080	3.42	Nov. 2 to Nov. 15.....	14	2,215	3,380	300	10	33	18	7.38	14.84	3.50	18.34
86	...do.....	900	2,981	3.31	.....do.....	14	2,216	3,413	432	14	48	36	5.13	10.31	2.43	12.74
87	...do.....	900	2,910	3.23	Nov. 3 to Nov. 17.....	15	2,260	3,331	421	15	47	36	5.37	10.79	2.52	13.31
88	...do.....	900	3,031	3.37	Nov. 5 to Nov. 17.....	13	2,200	3,442	411	14	46	19	5.35	10.76	2.33	13.09
89	...do.....	900	3,089	3.43	Nov. 6 to Nov. 18.....	13	2,010	3,550	461	15	51	14	4.36	8.75	2.08	10.83
90	...do.....	900	2,893	3.21	Nov. 7 to Nov. 18.....	12	1,839	3,297	404	14	45	19	4.55	9.14	2.19	11.33
91	...do.....	900	2,881	3.20	Nov. 8 to Nov. 19.....	12	1,847	3,564	683	24	76	17	2.70	5.42	1.33	6.75
92	...do.....	900	2,775	3.08	Nov. 9 to Nov. 20.....	12	1,798	3,336	561	20	62	17	3.19	6.43	1.63	8.06
93	...do.....	900	2,999	3.33	Nov. 10 to Nov. 20....	11	1,632	3,460	461	15	51	21	3.54	7.12	1.80	8.92
94	...do.....	900	3,026	3.36	Nov. 10 to Nov. 21....	12	1,769	3,448	422	14	47	19	4.19	8.42	2.02	10.44
95	...do.....	900	3,240	3.60	Nov. 12 to Nov. 20....	9	1,321	3,470	230	7	26	8	5.74	11.54	3.30	14.84
96	...do.....	900	2,965	3.29	Nov. 13 to Nov. 22....	10	1,470	3,280	315	11	35	8	4.67	9.37	2.81	12.18
97	...do.....	900	3,021	3.36	Nov. 14 to Nov. 24....	11	1,551	3,311	310	10	34	80	5.00	10.06	3.05	13.11
98	...do.....	900	3,338	3.71	Nov. 16 to Nov. 25....	10	1,392	3,560	222	7	25	21	6.27	12.60	3.93	16.53
99	...do.....	900	3,331	3.70	Nov. 17 to Nov. 26....	10	1,417	3,470	139	4	15	18	10.19	20.49	6.25	26.74
100	...do.....	900	3,259	3.62	Nov. 22 to Dec. 1.....	10	1,406	3,442	183	6	20	13	7.68	15.44	4.89	20.33

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT C, STATION 4, 1911.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1911.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
1	Broilers	864	1,248	1.4	June 13 to June 25	13	1,823	1,635	387	31	45	14	4.71	7.70	1.52	9.22
2	do	192	307	1.6	June 14 to June 27	14	426	383	76	25	40	7	5.61	9.12	1.84	10.96
3	do	336	480	1.4	June 22 to July 4	13	521	595	115	24	34	22	4.53	7.39	2.13	9.52
4	do	240	351	1.5	June 25 to July 8	14	321	412	61	17	25	19	5.26	8.74	4.30	13.04
5	do	320	492	1.5	June 20 to July 12	14	406	624	132	27	41	17	3.08	5.11	3.01	8.12
6	do	384	609	1.6	June 30 to July 13	14	518	807	198	33	52	17	2.62	4.30	2.44	6.74
7	do	448	730	1.6	July 2 to July 15	14	659	928	198	27	44	14	3.33	5.29	2.89	8.18
8	do	320	471	1.5	July 14 to July 17	14	493	625	154	33	48	26	3.20	5.09	2.62	7.71
9	do	448	678	1.5	July 6 to July 19	14	726	995	317	47	71	8	2.29	3.62	1.68	5.30
10	do	448	705	1.6	July 7 to July 20	14	753	986	281	40	63	6	2.68	4.19	1.76	5.95
11	do	576	1,046	1.8	July 8 to July 20	13	910	1,384	338	32	59	11	2.69	4.21	1.65	5.86
12	do	896	1,408	1.6	July 9 to July 22	14	1,559	2,029	621	44	69	14	2.51	3.91	1.38	5.29
13	do	704	1,077	1.5	July 11 to July 23	13	1,140	1,426	349	33	50	21	3.27	5.06	1.63	6.69
14	do	768	1,226	1.6	July 12 to July 24	13	1,244	1,685	459	37	60	19	2.71	4.20	1.29	5.49
15	do	898	1,343	1.5	July 14 to July 27	14	1,572	1,772	429	32	48	47	3.66	5.78	1.59	7.37
16	do	1,470	2,443	1.7	July 16 to July 29	14	2,573	3,368	925	38	63	44	2.78	4.32	1.14	5.46
17	Springers	768	1,349	1.8	July 18 to July 31	14	1,329	1,783	434	32	57	12	3.06	4.74	1.22	5.96
18	do	960	1,718	1.8	July 20 to Aug. 1	13	1,526	2,212	494	29	51	24	3.09	4.80	1.19	5.99
19	do	896	1,614	1.8	July 22 to Aug. 2	12	1,317	2,044	430	27	48	10	3.06	4.69	1.15	5.84
20	do	1,020	1,869	1.8	July 23 to Aug. 3	12	1,479	2,336	467	25	46	15	3.17	4.87	1.18	6.05
21	do	960	1,799	1.9	July 25 to Aug. 5	12	1,363	2,212	413	23	43	19	3.30	5.07	1.25	6.32
22	Broilers	1,280	2,159	1.7	July 26 to Aug. 6	12	1,766	2,764	605	28	47	20	2.92	4.46	1.12	5.58
23	do	1,080	1,697	1.6	July 27 to Aug. 7	12	1,469	2,280	583	34	54	26	2.52	3.84	.98	4.82
24	Springers	1,210	2,453	2.0	July 28 to Aug. 8	12	1,560	2,815	362	15	30	39	4.31	6.60	1.76	8.36
25	do	1,020	1,927	1.9	July 29 to Aug. 10	13	1,387	2,334	407	21	40	26	3.41	5.24	1.43	6.67
26	do	320	560	1.8	July 30 to Aug. 6	8	275	667	107	19	33	4	2.57	3.89	1.02	4.91
27	do	320	612	1.9	Aug. 1 to Aug. 9	9	298	678	66	11	21	3	4.52	6.99	1.85	8.84
28	do	1,520	3,045	2.0	Aug. 3 to Aug. 14	12	1,718	3,347	302	10	20	57	5.69	8.96	2.62	11.58
29	do	1,910	4,047	2.1	Aug. 8 to Aug. 20	13	2,349	4,545	498	12	26	44	4.72	7.59	2.34	9.93
30	do	960	1,733	1.8	Aug. 9 to Aug. 18	10	883	1,970	237	14	25	43	3.73	6.03	1.90	7.93

31	...do.....	2,646	5,505	2.1	Aug. 11 to Aug. 22...	12	3,142	6,072	567	10	22	69	5.54	8.85	2.79	11.64
32	...do.....	720	1,468	2.0	Aug. 12 to Aug. 24...	13	1,015	1,717	249	17	35	26	4.08	6.56	2.00	8.56
33	...do.....	1,920	3,836	2.0	Aug. 13 to Aug. 27...	15	3,418	4,800	964	25	50	42	3.55	5.96	1.65	7.61
34	...do.....	1,680	3,380	2.0	Aug. 15 to Aug. 28...	14	2,940	4,139	759	23	45	42	3.87	6.55	1.77	8.32
35	...do.....	1,350	2,839	2.1	Aug. 16 to Aug. 29...	14	2,403	3,550	711	25	53	40	3.38	5.81	1.56	7.37
36	...do.....	761	1,541	2.0	Aug. 17 to Aug. 30...	14	1,400	1,995	454	29	60	17	3.08	5.36	1.39	6.75
37	...do.....	1,040	2,295	2.2	Aug. 18 to Aug. 31...	14	1,945	3,007	712	31	69	12	2.73	4.79	1.23	6.02
38	...do.....	1,600	3,588	2.2	Aug. 20 to Sept. 3....	15	3,232	4,590	1,002	28	63	55	3.23	5.77	1.44	7.21
39	...do.....	320	722	2.3	Aug. 20 to Aug. 29...	10	432	884	162	22	51	9	2.67	4.66	1.20	5.86
40	...do.....	832	2,037	2.5	Aug. 22 to Sept. 4....	14	1,622	2,701	664	33	80	6	2.44	4.41	1.05	5.46
41	...do.....	832	1,880	2.3	Aug. 23 to Sept. 5....	14	1,656	2,475	595	32	72	18	2.78	5.03	1.19	6.22
42	...do.....	1,080	2,340	2.2	Aug. 24 to Sept. 6....	14	2,160	3,005	665	28	62	15	3.25	5.91	1.35	7.26
43	...do.....	896	2,073	2.3	Aug. 26 to Sept. 7....	13	1,604	2,615	542	26	61	11	2.96	5.34	1.24	6.58
44	...do.....	256	555	2.2	Aug. 27 to Sept. 4....	9	315	653	98	18	38	3	3.21	5.83	1.36	7.19
45	...do.....	832	2,053	2.5	Aug. 29 to Sept. 10...	13	1,489	2,088	435	21	52	9	3.42	6.16	1.40	7.56
46	...do.....	1,080	2,548	2.4	Aug. 30 to Sept. 10...	12	1,782	3,205	657	26	61	6	2.71	4.85	1.09	5.94
47	...do.....	1,400	3,206	2.3	Aug. 31 to Sept. 11...	12	2,156	4,064	858	27	61	21	2.51	4.76	1.06	5.82
48	...do.....	1,020	2,181	2.1	Sept. 1 to Sept. 12...	12	1,673	2,704	523	24	51	24	3.20	5.69	1.25	6.94
49	...do.....	1,150	2,487	2.2	Sept. 2 to Sept. 12...	11	1,714	3,135	648	26	56	21	2.65	4.70	1.03	5.73
50	...do.....	1,920	4,359	2.3	Sept. 3 to Sept. 13...	11	2,842	5,337	978	22	51	0	2.91	5.18	1.12	6.30
51	...do.....	384	846	2.2	Sept. 3 to Sept. 10...	8	415	1,058	212	25	55	0	1.96	3.44	.76	4.20
52	...do.....	1,530	3,471	2.3	Sept. 6 to Sept. 14...	9	1,836	4,060	589	17	39	4	3.12	5.61	1.22	6.83
53	...do.....	320	631	2.0	Sept. 6 to Sept. 15...	8	349	764	133	21	42	0	2.62	4.69	.99	6.58
54	...do.....	1,640	3,741	2.3	Sept. 7 to Sept. 18...	12	2,722	4,765	1,015	27	62	17	2.68	4.80	1.07	5.87
55	...do.....	1,280	2,987	2.3	Sept. 8 to Sept. 19...	12	2,189	3,718	731	24	57	18	2.99	5.32	1.17	6.49
56	...do.....	1,400	3,299	2.4	Sept. 9 to Sept. 20...	12	2,436	4,193	894	27	64	25	2.72	4.78	1.05	5.83
57	Roasters..	1,400	3,912	2.8	Sept. 10 to Sept. 21..	12	2,478	4,601	689	18	49	31	3.60	6.24	1.38	7.62
58	Broilers...	704	1,325	1.9	Sept. 10 to Sept. 24..	15	1,626	1,747	422	32	60	11	3.85	6.54	1.40	7.94
59	Roasters..	704	1,872	2.7	Sept. 12 to Sept. 22..	11	1,176	2,357	485	26	69	8	2.42	4.12	.93	5.05
60	...do.....	960	2,505	2.6	Sept. 13 to Sept. 22..	10	1,469	3,140	635	25	66	8	2.31	3.92	.89	4.81
61	Broilers...	518	853	1.7	Sept. 13 to Sept. 26..	14	1,166	1,272	419	49	81	9	2.78	4.59	.98	5.57
62	Roasters..	1,020	2,749	2.7	Sept. 14 to Sept. 24..	11	1,796	3,482	733	27	72	20	2.45	4.06	.89	4.95
63	Broilers...	643	1,011	1.6	Sept. 14 to Sept. 27..	14	1,466	1,512	501	50	78	19	2.93	4.80	1.03	5.83
64	Roasters..	1,010	2,569	2.5	Sept. 15 to Sept. 25..	11	1,848	3,204	635	25	63	6	2.91	4.76	.99	5.75
65	...do.....	1,280	3,574	2.8	Sept. 17 to Sept. 26..	10	2,314	4,210	636	18	50	7	3.48	5.58	1.09	6.67
66	Broilers...	512	807	1.6	Sept. 17 to Oct. 1....	15	1,290	1,161	354	44	69	8	3.64	5.80	1.23	7.03
67	Roasters..	896	2,501	2.8	Sept. 19 to Sept. 28..	10	1,541	2,890	389	15	43	0	3.96	6.22	1.29	7.51
68	...do.....	1,400	3,852	2.8	Sept. 20 to Sept. 29..	10	2,380	4,463	611	16	44	10	3.90	6.10	1.31	7.41
69	Broilers...	448	737	1.7	Sept. 20 to Oct. 3....	14	1,075	1,014	277	38	62	15	3.88	6.10	1.33	7.43
70	Roasters..	768	2,277	3.0	Sept. 21 to Oct. 1....	11	1,444	2,626	349	15	45	5	4.14	6.47	1.39	7.86
71	...do.....	768	2,135	2.8	Sept. 22 to Oct. 2....	11	1,436	2,464	329	15	43	8	4.36	6.84	1.47	8.31
72	...do.....	896	2,543	2.8	Sept. 23 to Oct. 2....	10	1,505	2,943	400	16	45	5	3.76	5.89	1.28	7.17
73	Broilers...	320	545	1.7	Sept. 23 to Oct. 5....	13	717	745	200	37	63	6	3.59	5.68	1.28	6.91
74	Roasters..	1,530	4,389	2.9	Sept. 24 to Oct. 5....	10	2,555	5,214	825	19	54	16	3.10	4.88	1.08	5.96
75	Broilers...	320	522	1.6	Sept. 24 to Oct. 8....	15	829	710	188	36	59	9	4.41	7.08	1.50	8.58

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT C, STATION 4, 1911—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1911.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
76	Broilers...	320	518	1.6	Sept. 26 to Oct. 9....	14	784	711	193	37	60	6	4.06	6.55	1.41	7.96
77	Roasters..	960	2,824	2.9	Sept. 27 to Oct. 8....	12	1,987	3,389	565	20	59	8	3.52	5.67	1.26	6.93
78	...do.....	1,540	3,834	2.9	Sept. 28 to Oct. 9....	12	2,814	4,732	898	23	67	17	3.13	5.09	1.09	6.18
79	Broilers...	320	538	1.7	Sept. 28 to Oct. 11...	14	797	745	207	39	65	11	3.85	6.28	1.33	7.61
80	Roasters..	896	2,668	3.0	Sept. 29 to Oct. 10...	12	1,935	3,221	553	21	62	6	3.50	5.72	1.20	6.92
81	Broilers...	322	505	1.6	Sept. 29 to Oct. 12...	14	811	685	180	36	56	4	4.51	7.41	1.56	8.97
82	Roasters..	896	2,740	3.1	Sept. 30 to Oct. 11...	12	1,971	1,331	591	22	66	12	3.34	5.47	1.11	6.58
83	...do.....	1,210	3,837	3.2	Oct. 1 to Oct. 12.....	12	2,662	4,562	725	19	60	22	3.67	6.04	1.22	7.26
84	Broilers...	256	401	1.6	Oct. 1 to Oct. 13.....	13	609	559	158	39	62	2	3.85	6.35	1.30	7.65
85	Roasters..	768	2,317	3.0	Oct. 3 to Oct. 13.....	11	1,567	2,643	326	14	42	9	4.81	8.01	1.63	9.64
86	...do.....	704	2,121	3.0	Oct. 4 to Oct. 15.....	12	1,563	2,515	394	19	56	2	3.97	6.65	1.32	7.97
87	...do.....	832	2,563	3.1	Oct. 6 to Oct. 16.....	11	1,689	2,989	426	17	51	9	3.96	6.68	1.31	7.99
88	...do.....	768	2,341	3.1	Oct. 7 to Oct. 17.....	11	1,551	2,685	344	15	45	10	4.51	7.64	1.50	9.14
89	Broilers...	192	313	1.6	Oct. 7 to Oct. 19.....	13	463	392	79	25	41	9	5.86	9.91	2.01	11.92
90	Roasters..	1,340	4,184	3.1	Oct. 8 to Oct. 18.....	11	2,734	4,817	633	15	47	11	4.32	7.32	1.48	8.80
91	Broilers...	704	1,098	1.6	Oct. 8 to Oct. 19.....	12	1,563	1,457	359	33	51	20	4.35	7.39	1.53	8.92
92	Roasters..	640	1,834	2.9	Oct. 10 to Oct. 17....	8	941	2,102	268	15	42	8	3.51	5.97	1.27	7.24
93	...do.....	832	2,558	3.1	Oct. 11 to Oct. 20....	10	1,548	2,946	388	15	47	6	3.99	6.73	1.52	8.25
94	Broilers...	320	529	1.7	Oct. 12 to Oct. 22....	11	666	693	164	31	51	3	4.06	6.71	1.56	8.27
95	Roasters..	1,020	3,181	3.1	.....do.....	11	2,122	3,748	567	18	56	9	3.74	6.19	1.44	7.63
96	...do.....	768	2,356	3.1	Oct. 13 to Oct. 23....	11	1,628	2,762	406	17	53	7	4.01	6.62	1.55	8.17
97	Broilers...	320	515	1.6	.....do.....	11	678	666	151	29	47	4	4.49	7.42	1.74	9.16
98	Roasters..	1,340	4,236	3.2	Oct. 15 to Oct. 25....	10	2,627	4,904	668	16	50	14	3.93	6.44	1.54	7.98
99	...do.....	704	2,204	3.1	Oct. 17 to Oct. 25....	9	1,274	2,456	252	11	36	10	5.06	8.16	2.12	10.28
100	...do.....	768	2,539	3.3	Oct. 18 to Oct. 25....	8	1,252	2,854	315	12	41	7	3.97	6.36	1.66	8.02
101	Broilers...	192	319	1.7	Oct. 18 to Oct. 30....	13	495	426	107	34	56	4	4.63	7.36	1.83	9.19
102	Roasters..	768	2,605	3.4	Oct. 20 to Oct. 26....	7	1,114	2,820	215	8	28	7	5.18	8.14	2.41	10.28
103	...do.....	832	2,743	3.3	Oct. 21 to Oct. 30....	10	1,664	3,021	278	10	33	16	5.99	9.34	2.31	11.65
104	...do.....	832	2,713	3.3	Oct. 22 to Oct. 31....	10	1,647	3,064	351	13	42	10	4.69	7.37	1.76	9.13
105	Broilers...	256	395	1.5	Oct. 22 to Nov. 1....	11	556	494	99	25	39	18	5.62	8.82	2.04	10.86

106	...do	192	285	1.5	Oct. 24 to Nov. 3	11	407	389	104	37	54	7	3.91	6.13	1.42	7.55
107	Roasters	1,020	3,315	3.3	Oct. 24 to Nov. 1	9	1,795	3,653	338	10	33	19	5.31	8.30	1.93	10.23
108	...do	1,400	4,494	3.2	Oct. 25 to Nov. 2	9	2,408	5,051	557	12	40	0	4.32	6.76	1.53	8.29
109	...do	832	2,740	3.3	Oct. 26 to Nov. 3	9	1,414	3,144	404	15	49	12	3.50	5.28	1.20	6.68
110	...do	960	3,009	3.1	Oct. 27 to Nov. 5	10	1,757	3,400	391	13	41	20	4.49	7.02	1.50	8.52
111	...do	705	2,269	3.2	Oct. 28 to Nov. 5	9	1,148	2,574	305	15	43	13	3.76	5.89	1.20	7.09
112	Broilers	263	419	1.6	Oct. 29 to Nov. 9	12	579	504	85	20	32	21	6.81	10.65	2.15	12.78
113	Roasters	1,210	3,863	3.2	Oct. 29 to Nov. 6	9	2,021	4,383	520	13	43	14	3.89	6.67	1.23	7.30
114	...do	704	2,112	3.0	Oct. 31 to Nov. 7	8	1,049	2,339	227	11	32	5	4.62	7.22	1.49	8.71
115	...do	1,660	4,969	3.0	Nov. 1 to Nov. 8	8	2,457	5,604	635	13	38	12	3.87	6.04	1.23	7.27
116	Broilers	320	498	1.6	Nov. 1 to Nov. 14	14	797	638	140	28	44	21	5.69	8.91	1.87	10.78
117	Roasters	768	2,319	3.0	Nov. 2 to Nov. 9	8	721	2,566	247	11	32	14	4.54	7.09	1.46	8.55
118	...do	1,470	4,467	3.0	Nov. 4 to Nov. 14	11	2,837	4,860	393	9	27	61	7.22	11.33	2.39	13.72
119	Broilers	256	409	1.6	Nov. 4 to Nov. 16	13	579	515	106	26	41	16	5.46	8.58	1.91	10.49
120	Roasters	1,470	4,746	3.2	Nov. 5 to Nov. 15	11	2,822	5,301	552	12	38	40	5.08	8.01	1.75	9.76
121	Broilers	320	556	1.7	Nov. 5 to Nov. 16	12	666	689	133	24	42	14	5.01	7.86	1.76	9.62
122	Roasters	2,110	6,860	3.3	Nov. 7 to Nov. 13	7	2,532	7,094	234	3	11	109	10.82	17.04	3.52	20.56
123	...do	1,790	5,753	3.2	Nov. 8 to Nov. 19	12	3,654	6,285	532	9	30	66	6.83	10.80	2.56	13.36
124	...do	768	2,384	3.1	Nov. 9 to Nov. 20	12	1,544	2,619	235	10	31	25	6.57	10.43	2.58	13.01
125	...do	768	2,434	3.2	Nov. 10 to Nov. 21	12	1,536	2,625	191	8	25	26	8.04	12.79	2.26	16.05
126	...do	1,080	3,648	3.4	Nov. 12 to Nov. 23	12	2,160	3,836	188	5	17	52	11.05	18.27	4.94	23.21
127	...do	768	2,469	3.2	Nov. 15 to Nov. 26	12	1,528	2,519	50	2	7	54	30.56	49.00	13.52	63.52
128	...do	893	2,676	3.0	Nov. 19 to Nov. 27	9	1,348	2,887	211	8	24	27	6.39	10.11	2.79	12.90
129	...do	640	2,216	3.5	Nov. 21 to Nov. 30	10	1,088	2,355	139	6	22	16	7.83	12.43	3.87	16.30
130	...do	704	2,167	3.1	Nov. 24 to Dec. 3	10	1,190	2,234	67	3	10	40	17.76	28.27	9.03	37.30
131	...do	448	1,252	2.8	Nov. 29 to Dec. 5	7	520	1,324	72	6	16	17	7.22	11.57	4.04	15.61
132	...do	960	3,177	3.3	Dec. 1 to Dec. 10	10	1,661	3,320	143	5	15	38	11.62	18.59	6.04	24.63
133	...do	960	3,400	3.5	Dec. 3 to Dec. 11	9	1,546	3,564	164	5	17	26	9.43	15.04	4.80	19.84
134	...do	576	1,984	3.4	Dec. 6 to Dec. 15	8	870	2,145	161	8	28	9	5.40	8.59	2.90	11.49

EXPERIMENT C, STATION 4, 1912.

					1912.											
1	Broilers	640	1,052	1.64	June 22 to July 7	16	1,267	1,451	399	38	62	10	3.18	5.82	1.96	7.78
2	...do	1,280	2,132	1.67	June 26 to July 10	15	2,368	2,914	782	37	61	17	3.03	5.52	2.36	7.88
3	...do	800	1,285	1.61	June 30 to July 15	16	1,416	1,708	423	33	53	20	3.35	6.11	2.36	8.47
4	...do	560	900	1.61	July 2 to July 16	15	924	1,191	291	32	52	8	3.18	5.83	2.31	8.17
5	...do	560	844	1.51	July 3 to July 16	14	851	1,088	244	29	44	8	3.49	6.40	2.61	9.01
6	...do	480	722	1.50	July 4 to July 17	14	725	902	180	25	38	15	4.03	7.39	2.91	10.30
7	...do	560	964	1.72	July 6 to July 21	16	991	1,181	217	23	39	7	4.57	8.47	2.87	11.34
8	...do	560	934	1.67	July 10 to July 22	13	762	1,133	199	21	36	13	3.83	7.18	2.22	9.40
9	...do	480	725	1.51	July 11 to July 23	13	648	905	180	25	38	10	3.60	6.77	2.06	8.83
10	...do	640	1,075	1.68	July 12 to July 23	12	806	1,278	203	19	32	14	3.97	7.50	2.14	9.64

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT C, STATION 4, 1912—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1912.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
11	Broilers	1,200	1,536	1.28	July 13 to July 24	12	1,524	1,790	254	17	21	24	6.00	11.34	3.17	14.51
12	do	2,160	3,615	1.67	July 14 to July 26	13	2,808	4,219	604	17	28	73	4.65	8.80	2.47	11.27
13	do	560	843	1.51	July 16 to July 28	13	739	938	95	11	17	50	7.78	14.67	3.95	18.62
14	do	960	1,599	1.67	July 17 to July 28	12	1,162	1,691	92	6	10	90	12.60	23.89	6.37	30.26
15	do	1,600	2,631	1.64	July 17 to July 29	13	2,080	3,149	518	20	32	44	4.02	7.60	2.04	9.64
16	do	1,680	2,560	1.52	July 20 to July 31	12	1,982	3,073	513	20	31	70	3.86	7.14	1.77	8.91
17	Springers	1,680	2,961	1.76	July 21 to Aug. 1	12	1,966	3,438	477	16	28	59	4.12	7.57	1.90	9.47
18	Broilers	1,600	2,329	1.46	July 22 to Aug. 2	12	1,872	2,920	591	25	37	62	3.17	5.79	1.49	7.28
19	do	1,360	2,324	1.71	July 23 to Aug. 4	13	1,782	2,796	472	20	35	25	3.78	6.83	1.70	8.53
20	do	560	962	1.72	July 24 to Aug. 5	13	750	1,173	211	22	38	28	3.55	6.40	1.49	7.89
21	do	1,200	2,028	1.69	do	13	1,608	2,558	530	26	44	27	3.03	5.46	1.27	6.73
22	Springers	1,680	2,986	1.78	July 24 to Aug. 6	14	2,470	3,719	733	25	44	22	3.37	6.07	1.38	7.45
23	Broilers	1,440	2,407	1.67	July 25 to Aug. 7	14	2,189	3,189	782	32	54	34	2.80	5.03	1.09	6.12
24	do	1,760	2,780	1.58	July 27 to Aug. 8	13	2,640	3,581	801	29	46	94	3.30	5.93	1.19	7.12
25	do	1,200	2,053	1.71	do	13	1,800	2,639	586	28	49	37	3.07	5.53	1.11	6.64
26	do	1,680	2,821	1.68	July 28 to Aug. 9	13	2,587	3,676	855	30	51	51	3.03	5.44	1.04	6.48
27	Springers	1,200	2,123	1.77	July 29 to Aug. 11	14	2,052	2,660	537	25	45	28	3.82	6.84	1.32	8.16
28	Broilers	640	1,004	1.57	July 30 to Aug. 11	13	1,037	1,343	339	34	53	.....	3.06	5.46	1.02	6.48
29	do	1,760	3,049	1.73	July 31 to Aug. 12	13	2,869	3,915	866	28	49	18	3.31	5.93	1.10	7.03
30	Springers	1,120	1,980	1.77	Aug. 1 to Aug. 12	12	1,714	2,471	491	25	44	26	3.49	6.27	1.14	7.41
31	do	1,600	2,917	1.82	Aug. 2 to Aug. 13	12	2,480	3,574	657	23	41	26	3.77	6.82	1.22	8.04
32	do	2,000	3,949	1.97	Aug. 5 to Aug. 14	10	2,600	4,779	830	21	42	17	3.13	5.69	.99	6.68
33	Broilers	880	1,450	1.65	Aug. 6 to Aug. 14	9	1,030	1,797	347	24	39	18	2.97	5.40	.96	6.36
34	Springers	2,560	4,578	1.79	Aug. 4 to Aug. 15	12	3,968	5,798	1,220	26	48	39	3.25	5.94	1.03	6.97
35	do	2,160	3,861	1.79	Aug. 7 to Aug. 18	12	3,326	4,921	1,060	28	59	46	3.14	5.73	1.06	6.79
36	do	1,360	2,610	1.92	Aug. 8 to Aug. 19	12	2,081	3,169	559	21	41	29	3.72	6.76	1.26	8.02
37	do	960	1,879	1.96	Aug. 9 to Aug. 19	11	1,334	2,253	374	20	39	6	3.57	6.52	1.23	7.75
38	do	1,200	2,361	1.97	Aug. 9 to Aug. 20	12	1,812	2,869	508	22	42	24	3.57	6.52	1.25	7.77
39	do	1,760	3,372	1.92	Aug. 10 to Aug. 20	11	2,429	3,947	575	17	33	45	4.22	7.68	1.50	9.18
40	do	1,920	3,579	1.86	Aug. 11 to Aug. 21	11	2,669	4,451	872	24	45	38	3.06	5.57	1.08	6.65

41	...do.....	1,200	2,336	1.95	Aug. 12 to Aug. 22...	11	1,704	2,864	528	22	44	10	3.23	5.86	1.14	7.00
42	...do.....	880	1,703	1.94	Aug. 10 to Aug. 22...	13	1,470	2,064	361	21	41	14	4.07	7.41	1.44	8.85
43	...do.....	2,320	4,468	1.93	Aug. 14 to Aug. 23...	10	3,016	5,367	899	20	39	17	3.36	6.09	1.21	7.30
44	...do.....	1,200	2,334	1.95	Aug. 15 to Aug. 25...	11	1,728	2,815	481	21	40	5	3.59	6.54	1.32	7.86
45	...do.....	1,200	2,409	2.01	Aug. 16 to Aug. 25...	10	1,560	2,818	409	17	34	3	3.81	6.98	1.41	8.39
46	...do.....	1,760	3,333	1.89	Aug. 17 to Aug. 26...	10	2,288	4,044	711	21	40	88	3.22	5.87	1.19	7.06
47	...do.....	1,760	3,554	2.02	Aug. 18 to Aug. 27...	10	2,270	4,247	693	20	39	24	3.28	5.97	1.24	7.21
48	...do.....	1,680	3,652	2.17	Aug. 18 to Aug. 28...	11	2,335	4,244	590	16	35	7	3.96	7.26	1.54	8.80
49	...do.....	1,520	3,133	2.06	Aug. 20 to Aug. 29...	10	1,961	3,682	549	18	36	17	3.57	6.53	1.41	7.94
50	...do.....	2,080	4,391	2.11	Aug. 21 to Aug. 30...	10	2,683	5,320	929	21	45	21	2.89	5.31	1.14	6.45
51	...do.....	1,360	2,695	1.98	Aug. 22 to Sept. 2...	12	2,081	3,293	598	22	44	17	3.48	6.34	1.41	7.75
52	...do.....	1,800	3,865	2.15	Aug. 23 to Sept. 3...	12	2,700	4,698	833	22	46	21	3.24	5.92	1.34	7.26
53	...do.....	1,600	3,247	2.03	Aug. 24 to Sept. 4...	12	2,384	3,900	653	20	41	25	3.65	6.62	1.49	8.11
54	...do.....	1,760	3,826	2.17	Aug. 25 to Sept. 5...	12	2,622	4,687	861	23	49	9	3.05	5.52	1.21	6.73
55	...do.....	1,760	3,867	2.20	Aug. 26 to Sept. 6...	12	2,622	4,614	747	19	42	21	3.51	6.34	1.41	7.75
56	...do.....	640	1,179	1.84	Aug. 27 to Sept. 8...	13	1,056	1,563	384	33	60	11	2.75	4.93	1.08	6.01
57	...do.....	1,440	2,806	1.95	Aug. 28 to Sept. 8...	12	2,203	3,660	854	30	59	30	2.58	4.62	1.01	5.63
58	...do.....	1,280	2,812	2.20	Aug. 29 to Sept. 9...	12	1,971	3,341	529	19	41	7	3.73	6.68	1.45	8.13
59	...do.....	1,600	3,494	2.18	Aug. 30 to Sept. 9...	11	2,272	4,119	625	18	39	15	3.64	6.50	1.41	7.91
60	...do.....	1,280	2,878	2.25	Aug. 31 to Sept. 10..	11	1,830	3,340	462	16	36	4	3.96	7.07	1.55	8.62
61	...do.....	2,720	6,089	2.24	Sept. 1 to Sept. 11...	11	3,862	7,149	1,060	17	39	15	3.64	6.49	1.44	7.93
62	...do.....	560	1,213	2.17	Sept. 3 to Sept. 12...	10	739	1,508	295	24	53	4	2.51	4.46	.99	5.45
63	...do.....	1,120	2,482	2.22	Sept. 4 to Sept. 15...	12	1,859	3,042	560	23	50	24	3.32	5.88	1.24	7.12
64	...do.....	1,440	3,048	2.12	Sept. 5 to Sept. 16...	12	2,448	3,810	762	25	53	.....	3.21	5.69	1.17	6.86
65	...do.....	1,520	3,254	2.14	Sept. 6 to Sept. 16...	11	2,371	4,080	826	25	54	18	2.87	5.08	1.07	6.15
66	...do.....	1,920	4,316	2.25	Sept. 7 to Sept. 17...	11	3,072	5,243	927	22	48	46	3.31	5.86	1.22	7.08
67	...do.....	1,680	3,904	2.32	Sept. 9 to Sept. 18...	10	2,520	4,827	923	24	55	29	2.73	4.81	1.00	5.81
68	...do.....	1,600	3,751	2.34	Sept. 9 to Sept. 19...	11	2,672	4,597	846	23	53	32	3.16	5.54	1.13	6.67
69	...do.....	1,200	2,596	2.16	Sept. 11 to Sept. 20..	10	1,884	3,385	789	30	66	18	2.39	4.18	.84	5.02
70	...do.....	1,600	3,597	2.25	Sept. 12 to Sept. 22..	11	2,832	4,637	1,040	29	65	6	2.72	4.80	.88	5.68
71	Broilers...	640	790	1.23	Sept. 9 to Sept. 22...	14	1,376	1,096	306	39	48	46	4.50	7.95	1.55	9.50
72	Springers .	1,280	3,027	2.36	Sept. 13 to Sept. 23..	11	2,317	3,807	780	26	61	14	2.97	5.23	.92	6.15
73	...do.....	1,520	3,837	2.52	Sept. 14 to Sept. 23..	10	2,493	4,519	682	18	45	16	3.66	6.46	1.11	7.57
74	...do.....	1,600	3,664	2.29	Sept. 15 to Sept. 24..	10	2,656	4,472	808	22	51	25	3.29	5.82	.99	6.81
75	...do.....	1,440	3,379	2.35	.....do.....	10	2,390	4,107	728	22	51	33	3.28	5.82	.99	6.81
76	...do.....	1,600	3,933	2.46	Sept. 18 to Sept. 25..	8	2,176	4,618	685	17	43	35	3.18	5.65	.91	6.56
77	...do.....	960	2,251	2.34	Sept. 17 to Sept. 25..	9	1,459	2,706	455	20	47	26	3.21	5.72	.95	6.67
78	...do.....	2,160	5,316	2.46	Sept. 19 to Sept. 26..	8	2,916	6,298	982	18	46	10	2.97	5.35	.86	6.21
79	...do.....	1,840	4,691	2.55	Sept. 20 to Sept. 26..	7	2,190	5,458	767	16	42	8	2.86	5.13	.82	5.95
80	...do.....	2,160	5,323	2.46	Sept. 21 to Sept. 29..	9	3,477	6,353	1,030	19	48	31	3.38	5.98	.92	6.90

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT C, STATION 4, 1912—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1912.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
81	Springers	1,200	2,981	2.48	Sept. 22 to Sept. 29	8	1,716	3,499	518	17	43	11	3.31	5.88	0.90	6.78
82	do	1,040	2,716	2.61	Sept. 22 to Sept. 30	9	1,695	3,349	633	23	61	2	2.68	4.70	.72	5.42
83	do	2,080	4,943	2.38	do	9	3,390	6,163	1,220	25	59	22	2.78	4.88	.75	5.63
84	do	2,160	5,454	2.53	Sept. 24 to Oct. 1	8	3,197	6,504	1,050	19	48	35	3.04	5.29	.84	6.13
85	do	1,840	4,522	2.46	Sept. 25 to Oct. 2	8	2,723	5,506	984	22	54	9	2.77	4.84	.77	5.61
86	do	2,080	5,387	2.59	Sept. 26 to Oct. 3	8	3,099	6,359	972	18	47	10	3.19	5.56	.90	6.46
87	do	880	2,157	2.45	Sept. 27 to Oct. 3	7	1,162	2,482	325	15	37	5	3.58	6.17	.98	7.15
88	do	1,200	2,916	2.43	Sept. 27 to Oct. 4	8	1,764	3,543	627	22	52	33	2.81	4.92	.80	5.72
89	do	1,840	4,466	2.43	Sept. 28 to Oct. 4	7	2,337	5,099	633	14	34	.....	3.69	6.39	1.05	7.44
90	do	2,800	6,758	2.41	Sept. 29 to Oct. 6	8	3,780	7,898	1,140	17	41	32	3.32	5.92	.93	6.85
91	do	720	1,873	2.60	do	8	972	2,100	227	12	32	14	4.28	7.64	1.21	8.85
92	do	2,720	6,571	2.42	Oct. 1 to Oct. 7	7	3,128	7,701	1,130	17	41	26	2.77	5.03	.82	5.85
93	do	2,080	5,049	2.43	Oct. 2 to Oct. 9	8	2,746	6,046	997	20	48	24	2.75	4.94	.86	5.80
94	do	1,440	3,551	2.47	Oct. 3 to Oct. 9	7	1,642	4,087	536	15	37	17	3.06	5.48	.97	6.45
95	do	800	1,733	2.17	Oct. 3 to Oct. 10	8	1,056	2,044	311	18	39	27	3.40	6.05	1.08	7.13
96	do	2,640	6,581	2.49	Oct. 5 to Oct. 11	7	3,062	7,741	1,160	18	44	19	2.64	4.67	.82	5.49
97	do	2,400	6,552	2.73	Oct. 6 to Oct. 14	9	3,648	7,612	1,060	16	44	24	3.44	6.09	.97	7.06
98	do	1,760	4,167	2.37	Oct. 6 to Oct. 15	10	2,974	5,227	1,060	15	60	16	2.81	5.03	.80	5.83
99	do	1,840	4,620	2.51	Oct. 8 to Oct. 15	8	2,558	5,419	799	17	43	12	3.20	5.64	.92	6.56
100	do	1,440	3,457	2.40	Oct. 9 to Oct. 16	8	2,002	4,066	609	18	42	21	3.29	5.82	.92	6.74
101	Broilers	800	1,482	1.85	Oct. 8 to Oct. 16	9	1,248	1,856	374	25	47	16	3.34	5.90	.96	6.86
102	Springers	1,760	4,408	2.50	Oct. 10 to Oct. 17	8	2,446	5,269	861	20	49	27	2.84	5.01	.78	5.79
103	do	1,920	4,541	2.37	Oct. 11 to 18	8	2,650	5,420	879	19	46	12	2.96	5.35	.83	6.18
104	Broilers	720	1,245	1.73	Oct. 12 to Oct. 20	9	1,123	1,602	357	29	49	15	3.15	5.61	.81	6.42
105	Springers	1,040	2,960	2.85	do	9	1,622	3,430	470	16	45	13	3.45	6.15	.89	7.04
106	Broilers	1,120	1,917	1.71	Oct. 13 to Oct. 23	11	2,128	2,558	641	34	57	14	3.32	5.91	.89	6.80
107	Roasters	1,760	4,972	2.83	Oct. 15 to Oct. 23	9	2,763	5,839	867	17	49	15	3.19	5.64	.89	6.53
108	Broilers	960	1,600	1.67	Oct. 15 to Oct. 24	10	1,690	2,085	485	30	51	17	3.48	6.18	.97	7.15
109	Roasters	1,040	3,156	3.03	Oct. 16 to Oct. 24	9	1,643	3,515	359	11	35	20	4.58	8.14	1.28	9.42
110	Broilers	640	1,139	1.78	Oct. 16 to Oct. 25	10	1,133	1,446	307	27	48	13	3.69	6.52	1.04	7.56

111	Roasters..	1,200	3,676	3.06	Oct. 17 to Oct. 25....	9	1,908	4,169	493	13	41	14	3.87	6.86	1.10	7.96
112	Broilers...	1,120	1,886	1.68	Oct. 17 to Oct. 27....	11	2,173	2,480	594	32	53	20	3.66	6.52	1.06	7.58
113	Roasters..	1,680	4,785	2.85	Oct. 18 to Oct. 27....	10	2,990	5,462	677	14	40	32	4.42	7.87	1.27	9.14
114	...do.....	1,120	3,409	3.04	Oct. 19 to Oct. 28....	10	1,994	3,775	366	11	33	14	5.45	9.73	1.53	11.26
115	Broilers...	560	953	1.70	Oct. 18 to Oct. 28....	11	1,098	1,219	266	28	48	10	4.13	7.35	1.18	8.53
116	Roasters..	1,360	4,118	3.03	Oct. 19 to Oct. 29....	11	2,652	4,636	518	13	38	15	5.12	9.14	1.50	10.64
117	...do.....	1,280	3,867	3.02	Oct. 20 to Oct. 30....	9	2,035	4,213	346	9	27	26	5.88	10.47	1.85	12.32
118	Broilers...	800	1,336	1.67	Oct. 20 to Nov. 4....	16	2,272	1,811	475	36	59	22	4.78	8.52	1.47	9.99
119	...do.....	880	1,581	1.80	Oct. 22 to Nov. 5....	15	2,323	2,010	429	27	49	40	5.41	9.64	1.70	11.34
120	Roasters..	720	2,181	3.03	Oct. 25 to Nov. 6....	13	1,627	2,565	384	18	53	13	4.24	7.50	1.37	8.87
121	Broilers...	480	805	1.68	Oct. 24 to Nov. 6....	14	1,176	1,071	266	33	55	13	4.42	7.83	1.41	9.24
122	Roasters..	1,520	4,688	3.08	Oct. 27 to Nov. 7....	12	3,131	5,281	593	13	39	20	5.28	9.31	1.69	11.00
123	...do.....	800	2,564	3.21	Oct. 26 to Nov. 7....	13	1,792	2,793	229	9	29	11	7.83	13.80	2.52	16.32
124	Broilers...	560	927	1.66	Oct. 27 to Nov. 8....	13	1,249	1,272	345	37	62	3	3.62	6.36	1.19	7.55
125	Roasters..	880	2,734	3.11	Oct. 29 to Nov. 9....	11	1,654	3,053	319	12	36	10	5.19	9.05	1.68	10.73
126	...do.....	1,040	3,223	3.10	Oct. 30 to Nov. 11...	13	2,319	3,624	401	12	39	20	5.78	9.96	1.92	11.88
127	Broilers...	480	793	1.65	.....do.....	13	1,070	1,027	234	30	49	20	4.57	7.88	1.52	9.40
128	Roasters..	720	2,100	2.92	Oct. 31 to Nov. 12...	13	1,627	2,416	316	15	44	13	5.15	8.77	1.69	10.46
129	Broilers...	480	785	1.64	.....do.....	13	1,085	1,028	243	31	51	27	4.47	7.60	1.46	9.06
130	...do.....	640	1,035	1.62	Nov. 3 to Nov. 14...	12	1,318	1,348	313	30	49	37	4.21	6.10	1.37	7.47
131	Roasters..	1,280	4,043	3.16	.....do.....	12	2,637	4,578	535	13	42	23	4.93	8.30	1.60	9.90
132	...do.....	880	2,800	3.18	Nov. 5 to Nov. 15...	11	1,681	3,156	356	13	40	11	4.72	7.81	1.58	9.39
133	...do.....	960	2,828	2.95	Nov. 6 to Nov. 17...	12	1,997	3,213	385	14	40	16	5.19	8.58	1.72	10.30
134	Broilers...	720	1,264	1.76	Nov. 5 to Nov. 17...	13	1,678	1,622	358	28	50	22	4.69	7.46	1.49	8.95
135	...do.....	400	633	1.58	Nov. 6 to Nov. 18...	13	900	843	210	33	53	10	4.29	7.10	1.45	8.55
136	Roasters..	800	2,469	3.09	Nov. 8 to Nov. 18...	11	1,536	2,781	312	13	39	10	4.92	8.23	1.69	9.92
137	Broilers...	400	652	1.63	Nov. 8 to Nov. 19...	12	840	849	197	30	49	8	4.26	7.11	1.48	8.59
138	...do.....	400	674	1.69	Nov. 9 to Nov. 20...	12	844	943	269	40	67	3	3.14	5.22	1.10	6.32
139	Roasters..	1,920	6,037	3.14	Nov. 10 to Nov. 20..	11	3,725	6,777	740	12	39	25	5.03	8.35	1.74	10.09
140	...do.....	640	1,973	3.08	Nov. 12 to Nov. 21..	10	1,120	2,165	192	10	30	10	5.83	9.70	2.10	11.80
141	Broilers...	560	890	1.59	Nov. 10 to Nov. 21..	12	1,170	1,206	316	35	56	10	3.70	6.17	1.31	7.48
142	Roasters..	1,040	3,338	3.21	Nov. 13 to Nov. 25..	13	2,319	3,672	334	7	32	40	6.94	11.40	2.46	13.86
143	...do.....	880	2,822	3.21	Nov. 14 to Nov. 25..	12	1,804	3,103	281	10	32	20	6.42	10.52	2.28	12.80
144	...do.....	1,200	4,179	3.48	Nov. 15 to Nov. 26..	12	2,436	4,419	240	6	20	36	10.15	16.65	3.65	20.30
145	...do.....	2,160	7,304	3.38	Nov. 17 to Nov. 28..	12	4,277	7,730	426	6	20	58	10.04	16.38	3.70	20.08
146	Broilers...	320	536	1.68	Nov. 15 to Nov. 28..	14	752	688	152	28	48	17	4.95	8.09	1.79	9.88
147	...do.....	640	1,038	1.62	Nov. 16 to Nov. 28..	13	1,376	1,284	246	24	38	30	5.59	9.16	2.06	11.22

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT D, STATION 2, 1911.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1911.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
1	Broilers...	480	831	1.7	July 25 to Aug. 7....	14	979	1,143	312	38	65	3	3.14	5.98	1.26	7.15
2	...do.....	800	1,379	1.7	July 27 to Aug. 10...	15	1,664	1,863	484	35	61	9	3.44	6.45	1.29	7.74
3	Springers .	960	2,008	2.1	July 28 to Aug. 11...	15	1,968	2,519	511	25	53	21	3.85	7.46	1.45	8.91
4	...do.....	1,360	2,452	1.8	July 29 to Aug. 14...	17	3,033	3,350	898	37	66	18	3.38	6.63	1.29	7.92
5	...do.....	800	1,401	1.8	July 30 to Aug. 14...	16	1,688	1,853	452	32	57	26	3.73	7.35	1.43	8.78
6	...do.....	640	1,145	1.8	Aug. 1 to Aug. 15...	15	1,286	1,541	396	35	62	14	3.25	6.37	1.23	7.60
7	...do.....	1,120	2,129	1.9	Aug. 2 to Aug. 16...	15	2,262	2,608	479	23	43	56	4.72	9.24	1.73	10.97
8	...do.....	720	1,346	1.9	Aug. 4 to Aug. 17...	14	1,310	1,618	272	20	38	23	4.82	9.61	1.80	11.41
9	...do.....	1,500	2,906	1.9	Aug. 5 to Aug. 18...	14	2,745	3,464	558	19	37	43	4.92	9.79	1.83	11.62
10	...do.....	1,880	3,599	1.9	Aug. 6 to Aug. 20...	15	3,666	4,597	998	28	53	50	3.67	7.35	1.41	8.76
11	...do.....	400	718	1.8	Aug. 8 to Aug. 22...	15	764	920	202	28	51	14	3.78	7.56	1.58	9.14
12	...do.....	1,100	2,102	1.9	Aug. 11 to Aug. 24..	14	2,035	2,726	624	30	57	28	3.26	6.56	1.36	7.92
13	...do.....	2,540	5,182	2.0	Aug. 12 to Aug. 27..	16	5,613	6,516	1,334	26	53	96	4.21	8.43	1.73	10.16
14	...do.....	560	1,122	2.0	Aug. 15 to Aug. 29..	15	1,193	1,501	379	34	68	13	3.15	6.32	1.33	7.65
15	...do.....	560	1,234	2.2	Aug. 18 to Aug. 31..	14	1,142	1,592	358	29	64	15	3.19	6.48	1.36	7.84
16	...do.....	1,600	3,533	2.2	Aug. 20 to Sept. 3...	15	3,584	4,517	984	28	62	32	3.64	7.41	1.50	8.91
17	...do.....	832	1,857	2.2	Aug. 24 to Sept. 5...	13	1,639	2,403	546	29	66	9	3.00	6.05	1.17	7.22
18	...do.....	1,150	2,676	2.3	Aug. 24 to Sept. 7...	14	2,373	3,434	758	28	66	9	3.13	6.39	1.22	7.61
19	...do.....	1,020	2,401	2.4	Aug. 26 to Sept. 7...	13	1,925	3,066	665	28	65	13	2.89	5.79	1.14	6.93
20	...do.....	1,470	3,238	2.2	Aug. 27 to Sept. 10..	15	3,165	4,321	1,083	33	74	24	2.92	5.76	1.11	6.87
21	...do.....	1,100	2,510	2.3	Aug. 29 to Sept. 6...	9	1,408	3,045	535	21	49	5	2.63	5.35	1.01	6.36
22	...do.....	1,060	2,399	2.3	Aug. 31 to Sept. 13..	14	2,162	3,158	759	32	72	11	2.85	5.67	1.06	6.73
23	...do.....	1,140	2,683	2.4	Sept. 1 to Sept. 14...	14	2,311	3,279	596	22	52	19	3.88	7.71	1.48	9.19
24	...do.....	1,480	3,202	2.2	Sept. 2 to Sept. 11...	10	2,161	3,997	795	25	54	24	2.72	5.31	.99	6.30
25	...do.....	1,380	3,162	2.3	Sept. 3 to Sept. 12...	10	1,975	3,870	708	22	51	13	2.79	5.46	1.04	6.50
26	Broilers...	512	1,065	2.1	Sept. 6 to Sept. 19...	14	1,055	1,418	353	33	69	17	2.99	6.01	1.13	7.14
27	...do.....	768	1,419	1.9	Sept. 7 to Sept. 20...	14	1,628	1,934	515	36	67	33	3.16	6.38	1.18	7.56
28	Roasters ..	572	1,278	2.2	Sept. 7 to Sept. 15...	9	744	1,562	284	22	50	12	2.62	5.26	1.01	6.27
29	Broilers...	560	1,120	2.0	Sept. 8 to Sept. 21...	14	1,193	1,430	310	28	55	10	3.85	7.86	1.45	9.31
30	Roasters ..	864	2,301	2.7	Sept. 8 to Sept. 15...	8	994	2,483	182	8	21	15	5.46	11.10	2.14	13.24

31	Broilers...	800	1,616	2.0	Sept. 9 to Sept. 22...	14	1,696	2,075	459	28	57	31	3.70	7.65	1.39	9.04
32	...do.....	1,020	2,000	2.0	Sept. 10 to Sept. 24..	15	2,387	2,618	618	31	61	31	3.86	8.09	1.42	9.51
33	Roasters..	1,230	3,264	2.7	Sept. 10 to Sept. 17..	8	1,439	3,710	446	14	36	15	3.23	6.68	1.24	7.92
34	...do.....	952	2,459	2.6	Sept. 12 to Sept. 19..	8	1,142	2,800	341	14	36	22	3.35	6.95	1.28	8.23
35	Broilers...	800	1,426	1.8	Sept. 13 to Sept. 26..	14	1,816	1,940	514	36	64	41	3.53	7.38	1.29	8.67
36	Roasters..	1,480	3,741	2.5	Sept. 13 to Sept. 22..	10	2,294	4,207	466	12	32	61	4.92	10.13	1.81	11.94
37	Broilers...	500	853	1.7	Sept. 14 to Sept. 27..	14	1,160	1,205	352	41	70	14	3.30	6.95	1.19	8.14
38	Roasters..	1,140	3,119	2.7	Sept. 14 to Sept. 22..	9	1,619	3,502	383	12	34	30	4.23	8.78	1.52	10.30
39	...do.....	1,230	3,264	2.7	Sept. 15 to Sept. 24..	10	2,030	3,978	714	22	58	14	2.84	5.96	.98	6.94
40	Broilers...	380	585	1.5	Sept. 15 to Sept. 28..	14	889	826	241	41	63	13	3.69	7.81	1.34	9.15
41	Roasters..	600	1,707	2.9	Sept. 16 to Sept. 24..	9	900	1,940	233	14	39	3	3.86	8.06	1.34	9.40
42	...do.....	1,350	3,754	2.8	Sept. 17 to Sept. 25..	9	2,025	4,315	561	15	42	10	3.61	7.60	1.28	8.88
43	Broilers...	480	869	1.8	Sept. 17 to Oct. 1....	15	1,219	1,198	329	38	69	12	3.71	7.78	1.34	9.12
44	Roasters..	878	2,375	2.7	Sept. 19 to Sept. 26..	8	1,212	2,827	452	19	51	3	2.68	5.73	.95	6.68
45	...do.....	572	1,554	2.7	Sept. 21 to Sept. 28..	8	784	1,708	154	10	27	8	5.09	10.96	1.90	12.86
46	Broilers...	320	608	1.9	Sept. 21 to Oct. 4....	14	784	788	180	30	56	7	4.36	9.28	1.58	10.86
47	Roasters..	832	2,269	2.7	Sept. 22 to Sept. 29..	8	1,140	2,623	354	16	43	0	3.22	6.91	1.20	8.11
48	Broilers...	400	690	1.7	Sept. 22 to Oct. 5....	14	1,000	888	198	29	50	9	5.05	10.69	1.80	12.49
49	...do.....	320	488	1.5	Sept. 23 to Oct. 6....	14	806	673	185	38	58	5	4.36	9.25	1.56	10.81
50	Roasters..	1,020	2,856	2.8	Sept. 23 to Oct. 1....	9	1,601	3,363	507	18	50	6	3.16	6.68	1.17	7.85
51	Broilers...	320	549	1.7	Sept. 24 to Oct. 8....	15	870	739	190	35	59	6	4.58	9.58	1.63	11.21
52	Roasters..	1,380	3,821	2.8	Sept. 24 to Oct. 2....	9	2,167	4,604	783	20	57	4	2.77	5.83	1.02	6.85
53	...do.....	1,460	4,129	2.8	Sept. 26 to Oct. 3....	8	2,073	4,657	528	13	36	14	3.93	7.99	1.44	9.43
54	Broilers...	340	562	1.7	Sept. 27 to Oct. 10...	14	887	783	221	39	65	9	4.01	8.23	1.37	9.60
55	Roasters..	1,050	2,827	2.7	Sept. 27 to Oct. 4....	8	1,481	3,272	445	16	42	14	3.33	7.06	1.23	9.29
56	...do.....	1,540	4,315	2.8	Sept. 28 to Oct. 5....	8	2,218	5,144	829	19	54	27	2.68	5.59	.95	6.54
57	Broilers...	600	1,002	1.7	Sept. 28 to Oct. 11...	14	1,578	1,389	387	39	65	14	4.08	8.36	1.36	9.72
58	Roasters..	1,440	3,963	2.8	Sept. 29 to Oct. 6....	8	2,117	4,638	675	17	47	9	3.14	6.57	1.07	7.64
59	Broilers...	340	534	1.6	Sept. 29 to Oct. 12...	14	915	757	223	42	66	5	4.10	8.35	1.33	9.68
60	Roasters..	1,080	3,337	3.1	Oct. 2 to Oct. 9.....	8	1,663	3,699	362	11	34	8	4.59	9.34	1.52	10.86
61	...do.....	896	2,593	2.9	Oct. 3 to Oct. 19....	8	1,416	2,959	366	14	41	8	3.87	7.81	1.25	9.06
62	...do.....	1,790	5,329	3.0	Oct. 4 to Oct. 11....	8	2,828	6,073	744	14	42	11	3.80	7.67	1.20	8.87
63	Broilers...	480	792	1.7	Oct. 5 to Oct. 18....	14	1,525	1,073	280	35	58	7	4.73	9.84	1.53	11.37
64	Roasters..	2,140	6,178	2.9	Oct. 5 to Oct. 12....	8	3,445	7,105	927	15	43	10	3.72	7.41	1.13	8.54
65	...do.....	684	2,109	3.1	Oct. 7 to Oct. 13....	7	985	2,357	248	12	36	8	3.97	7.89	1.21	9.10
66	...do.....	2,170	6,653	3.1	Oct. 8 to Oct. 15....	8	3,515	7,470	817	12	38	27	4.30	8.69	1.33	10.02
67	Broilers...	320	574	1.8	Oct. 8 to Oct. 22....	15	938	757	183	32	57	9	5.13	10.87	1.69	12.56
68	Roasters..	956	2,856	3.0	Oct. 10 to Oct. 17....	8	1,530	3,254	398	14	42	4	3.84	8.22	1.23	9.45
69	...do.....	1,210	3,613	3.0	Oct. 11 to Oct. 18 ...	8	1,888	4,146	533	15	44	11	3.54	7.67	1.18	8.85
70	...do.....	1,860	5,795	3.1	Oct. 12 to Oct. 19....	8	2,883	6,581	786	14	42	11	3.67	8.00	1.23	9.23
71	...do.....	1,330	3,982	3.0	Oct. 13 to Oct. 20....	8	2,035	4,580	598	15	45	7	3.40	7.54	1.18	8.72
72	...do.....	1,120	3,590	3.2	Oct. 14 to Oct. 22....	9	1,893	4,107	517	14	46	4	3.66	8.14	1.30	9.44
73	Broilers...	240	385	1.6	Oct. 15 to Oct. 29....	15	706	542	157	41	65	10	4.50	10.00	1.65	11.65
74	Roasters..	1,400	4,399	3.2	Oct. 15 to Oct. 23....	9	2,408	4,856	457	10	33	29	5.27	11.73	1.84	13.57
75	...do.....	1,460	4,487	3.1	Oct. 17 to Oct. 24 ...	8	2,263	5,032	545	12	37	15	4.15	9.27	1.45	10.72

Details of feeding experiments in 1911 and 1912—Continued.

EXPERIMENT D, STATION 2, 1911—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1911.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
76	Roasters..	1,020	3,146	3.1	Oct. 18 to Oct. 25....	8	1,601	3,514	268	12	36	8	4.35	9.48	1.55	11.03
77	...do.....	1,610	5,029	3.1	Oct. 19 to Oct. 26....	8	2,560	5,649	620	12	39	18	4.13	8.93	1.28	10.41
78	Broilers...	400	649	1.6	Oct. 20 to Nov. 2....	14	1,080	844	195	30	49	18	5.55	12.29	2.26	14.55
79	Roasters..	960	3,201	3.3	Oct. 20 to Oct. 27....	8	1,546	3,508	307	9	32	11	5.04	10.91	1.84	12.75
80	...do.....	956	3,014	3.2	Oct. 21 to Oct. 27....	7	1,358	3,388	374	12	39	7	3.63	7.82	1.33	9.15
81	...do.....	1,280	4,027	3.2	Oct. 22 to Oct. 29....	8	2,099	4,544	517	13	40	19	4.06	8.96	1.54	10.50
82	Broilers...	320	537	1.7	Oct. 22 to Nov. 3....	13	806	734	197	37	62	12	4.09	9.08	1.71	10.79
83	Roasters..	832	2,524	3.0	Oct. 24 to Oct. 31....	8	1,290	2,867	343	14	41	13	3.76	8.32	1.62	9.34
84	...do.....	1,470	4,642	3.2	Oct. 26 to Nov. 2....	8	2,205	5,155	513	11	35	24	4.30	9.77	1.92	11.79
85	...do.....	1,340	4,414	3.3	Oct. 29 to Nov. 5....	8	1,876	4,879	465	11	35	28	4.03	8.96	1.85	10.81
86	...do.....	1,280	3,944	3.1	Nov. 1 to Nov. 7....	7	1,574	4,273	329	8	26	8	4.79	10.58	1.99	12.57
87	...do.....	1,340	4,231	3.2	Nov. 2 to Nov. 8....	7	1,675	4,762	531	13	40	12	3.15	6.79	1.26	8.05
88	...do.....	1,140	3,817	3.4	Nov. 4 to Nov. 9....	6	1,186	4,120	303	8	27	15	3.91	8.28	1.50	9.78
89	...do.....	1,700	5,590	3.3	Nov. 7 to Nov. 13...	7	2,227	6,044	454	8	27	24	4.91	9.92	1.57	11.49
90	...do.....	1,800	5,624	3.1	Nov. 8 to Nov. 14...	7	2,358	6,086	462	8	26	18	5.10	10.09	1.68	11.77
91	...do.....	2,040	6,482	3.2	Nov. 9 to Nov. 15...	7	2,754	7,242	760	12	37	8	3.62	7.41	1.15	8.56
92	...do.....	2,130	6,768	3.2	Nov. 10 to Nov. 16..	7	2,876	7,385	617	9	29	33	4.66	9.46	1.52	10.98
93	...do.....	1,330	4,459	3.4	Nov. 11 to Nov. 19..	9	2,221	4,778	319	7	24	8	6.96	14.47	2.50	16.97
94	...do.....	1,240	3,766	3.0	Nov. 12 to Nov. 19...	8	1,872	4,066	300	8	24	23	6.24	13.06	2.31	15.37
95	...do.....	1,210	3,595	3.0	Nov. 15 to Nov. 21..	7	1,525	3,971	376	11	31	16	4.06	8.88	1.64	10.52
96	...do.....	1,340	4,062	3.0	Nov. 17 to Nov. 22...	6	1,380	4,374	312	8	23	13	4.42	9.66	1.89	11.55
97	...do.....	1,340	4,316	3.2	Nov. 19 to Nov. 24...	6	1,434	4,666	350	8	26	15	4.10	8.77	1.76	10.53
98	...do.....	1,080	3,596	3.3	Nov. 22 to Nov. 27...	6	1,220	3,786	190	5	18	17	6.42	13.47	2.62	16.09
99	...do.....	1,530	5,528	3.6	Nov. 24 to Nov. 30...	7	1,958	5,645	117	2	8	27	16.74	35.31	6.80	42.11
100	...do.....	1,080	3,592	3.3	Nov. 26 to Dec. 1....	6	1,112	3,914	322	9	30	4	3.45	7.48	1.41	8.89
101	...do.....	1,530	5,114	3.3	Nov. 29 to Dec. 4....	6	1,760	5,593	479	9	31	21	3.67	8.08	1.34	9.42
102	...do.....	896	3,416	3.8	Dec. 3 to Dec. 8.....	6	1,030	3,488	72	2	8	16	14.31	30.86	6.72	37.58
103	...do.....	768	2,449	3.2	Dec. 6 to Dec. 11....	6	914	2,667	218	9	28	15	4.19	9.06	2.39	11.45

					1912.											
1	Springers	800	1,488	1.86	Aug. 7 to Aug. 20	14	1,512	1,834	346	23	43	17	4.37	10.27	1.66	11.93
2	do	480	919	1.91	Aug. 6 to Aug. 20	15	974	1,120	201	22	42	7	4.85	11.51	1.86	13.37
3	do	1,840	3,496	1.90	Aug. 8 to Aug. 23	16	2,938	4,536	1,040	30	57	31	3.79	8.90	1.36	10.26
4	do	400	786	1.97	Aug. 10 to Aug. 25	16	812	960	174	22	44	15	4.67	10.92	1.68	12.60
5	do	640	1,104	1.73	Aug. 9 to Aug. 25	17	1,440	1,485	381	35	60	6	3.78	8.78	1.36	10.14
6	do	1,600	2,882	1.80	Aug. 11 to Aug. 26	16	3,232	3,529	647	22	40	45	4.99	11.67	1.83	13.50
7	do	640	1,234	1.93	Aug. 13 to Aug. 27	15	1,171	1,532	298	24	47	19	3.93	9.15	1.44	10.59
8	do	1,040	1,957	1.88	Aug. 14 to Aug. 28	15	1,862	2,455	498	25	48	28	3.74	8.73	1.38	10.11
9	do	320	621	1.94	Aug. 16 to Aug. 29	14	515	665	44	7	14	18	11.70	27.20	4.50	31.70
10	do	400	831	2.08	Aug. 15 to Aug. 29	15	704	949	118	14	30	24	5.97	13.93	2.24	16.17
11	do	800	1,623	2.03	Aug. 17 to Aug. 30	14	1,264	1,853	230	14	29	35	5.50	12.80	2.19	14.99
12	do	1,480	3,678	2.49	Aug. 19 to Sept. 1	14	2,383	4,521	843	23	57	47	2.83	6.48	1.12	7.60
13	do	580	1,175	2.03	Aug. 22 to Sept. 2	12	818	1,446	271	23	47	11	3.02	6.83	1.20	8.03
14	do	660	1,414	2.14	Aug. 21 to Sept. 2	13	1,023	1,667	253	18	38	14	4.04	9.21	1.54	10.75
15	do	820	1,631	1.99	Aug. 20 to Sept. 2	14	1,337	2,000	369	23	45	12	3.62	8.24	1.42	9.66
16	do	704	1,554	2.21	Aug. 23 to Sept. 3	12	1,007	1,758	204	13	29	9	4.94	11.04	1.97	13.01
17	do	704	1,495	2.12	Aug. 24 to Sept. 3	11	915	1,767	272	18	39	6	3.36	7.48	1.37	8.85
18	do	448	1,000	2.23	Aug. 27 to Sept. 4	9	483	1,196	196	20	44	3	2.46	5.51	1.03	6.54
19	do	2,140	4,576	2.14	Aug. 25 to Sept. 4	11	2,761	5,464	888	19	42	30	3.11	6.96	1.30	8.26
20	do	640	1,227	1.92	Aug. 29 to Sept. 8	11	864	1,498	271	22	42	5	3.19	7.11	1.42	8.53
21	do	1,280	2,689	2.10	Aug. 28 to Sept. 8	12	1,869	3,184	495	18	39	12	3.78	8.43	1.68	10.11
22	do	448	922	2.06	Aug. 31 to Sept. 9	10	556	1,104	182	20	41	4	3.06	7.34	1.40	8.74
23	do	896	1,897	2.12	Aug. 31 to Sept. 10	11	1,210	2,052	155	8	17	8	7.81	17.57	3.64	21.21
24	do	3,380	7,334	2.17	Sept. 1 to Sept. 11	11	4,664	8,424	1,090	15	32	23	4.28	9.80	2.05	11.85
25	do	240	543	2.26	Sept. 3 to Sept. 11	9	276	623	80	15	3	13	3.45	10.95	1.71	12.66
26	do	692	1,443	2.09	Sept. 4 to Sept. 15	12	1,135	1,763	320	22	46	10	3.55	8.07	1.62	9.69
27	do	512	1,123	2.19	Sept. 5 to Sept. 15	11	778	1,352	229	20	45	20	3.40	7.74	1.54	9.28
28	do	1,470	3,235	2.20	Sept. 6 to Sept. 16	11	2,323	4,095	860	27	59	35	2.70	6.14	1.16	7.30
29	do	1,760	3,871	2.20	Sept. 7 to Sept. 17	11	2,851	4,725	854	22	49	33	3.34	7.42	1.38	8.80
30	do	1,380	3,084	2.23	Sept. 8 to Sept. 18	11	2,318	3,757	673	22	49	38	3.44	7.57	1.33	8.90
31	do	384	802	2.09	Sept. 10 to Sept. 18	9	5,530	1,007	205	26	53	4	2.70	5.94	1.00	6.94
32	do	704	1,639	2.33	Sept. 11 to Sept. 18	8	936	2,064	425	26	60	4	2.20	4.79	.78	5.57
33	do	576	1,322	2.29	Sept. 12 to Sept. 19	8	766	1,540	218	16	38	1	3.51	7.43	1.16	8.59
34	do	896	2,160	2.41	Sept. 13 to Sept. 19	7	1,057	2,541	381	18	43	7	2.77	5.76	.87	6.63
35	do	576	1,326	2.30	Sept. 14 to Sept. 20	7	691	1,600	274	21	48	2	2.52	5.17	.78	5.95
36	do	512	1,352	2.64	Sept. 17 to Sept. 22	6	532	1,551	199	15	39	.....	2.67	5.22	.77	5.99
37	do	2,010	5,028	2.50	Sept. 18 to Sept. 24	7	2,492	5,934	906	18	45	46	2.75	5.56	.78	6.34
38	do	3,410	8,577	2.52	Sept. 20 to Sept. 27	8	5,115	9,907	1,330	16	39	30	3.85	7.85	1.00	8.85
39	do	2,910	7,167	2.46	Sept. 21 to Sept. 30	10	5,733	8,737	1,570	22	54	34	3.65	7.41	.85	8.26
40	do	2,580	6,516	2.52	Sept. 21 to Oct. 1	11	5,728	8,046	1,530	24	59	20	3.74	7.45	.86	8.31

Details of feeding experiments in 1911 and 1912—Continued

EXPERIMENT D, STATION 2, 1912—Continued.

Lot.	Class.	Number in.	Total weight in.	Average weight in.	Dates fed.	Days fed.	Total feed.	Total weight out.	Total gain.	Per cent gain.	Gain per 100 head.	Dead.	Grain per pound of gain.	Total cost of feed per pound of gain.	Cost of labor per pound of gain.	Total cost per pound of gain.
		Head.	*Pounds.*	*Pounds.*	1912.		*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Head.*	*Pounds.*	*Cents.*	*Cents.*	*Cents.*
41	Springers	2,780	7,100	2.55	Sept. 23 to Oct. 2	10	5,782	8,560	1,460	21	53	39	3.96	7.90	0.90	8.80
42	do	1,240	3,100	2.50	Sept. 24 to Oct. 3	10	2,616	3,811	711	23	57	20	3.68	7.27	.84	8.11
43	do	960	2,439	2.54	Sept. 25 to Oct. 4	10	1,997	2,928	489	20	51	5	4.08	8.11	.94	9.05
44	do	1,470	3,815	2.60	Sept. 26 to Oct. 6	11	3,293	4,503	688	18	47	15	4.79	9.57	1.13	10.70
45	do	576	1,434	2.49	Sept. 27 to Oct. 6	10	1,158	1,775	341	24	59	6	3.40	6.82	.81	7.63
46	do	4,180	10,571	2.53	Sept. 29 to Oct. 8	10	8,444	12,741	2,170	21	52	38	3.89	7.78	.96	8.74
47	do	1,990	5,247	2.64	Sept. 29 to Oct. 9	11	4,438	6,065	818	16	41	30	5.43	10.83	1.36	12.19
48	do	660	1,772	2.68	Oct. 1 to Oct. 9	9	1,175	2,092	320	18	48	4	3.67	7.34	.99	8.33
49	do	1,840	5,036	2.74	Oct. 3 to Oct. 11	9	3,110	5,603	567	11	31	36	5.49	11.23	1.53	12.76
50	do	1,540	4,149	2.69	Oct. 5 to Oct. 15	11	3,265	4,754	605	15	39	28	5.40	10.89	1.38	12.27
51	do	800	2,315	2.89	do	11	1,696	2,692	377	16	47	16	4.50	9.07	1.15	10.22
52	do	1,500	4,232	2.82	Oct. 6 to Oct. 16	11	3,210	4,870	638	15	43	28	5.03	10.11	1.25	11.36
53	do	2,390	6,796	2.84	Oct. 9 to Oct. 21	13	6,118	7,946	1,150	17	48	55	5.32	10.21	1.31	11.52
54	do	1,080	2,789	2.58	Oct. 11 to Oct. 22	12	2,506	3,331	542	19	50	23	4.62	8.79	1.16	9.95
55	do	1,180	3,181	2.70	Oct. 10 to Oct. 23	14	3,245	3,579	398	13	34	28	8.15	15.60	2.02	17.62
56	do	960	2,606	2.71	Oct. 11 to Oct. 23	13	2,419	3,036	430	17	45	39	5.63	10.72	1.41	12.13
57	do	1,920	5,198	2.71	Oct. 11 to Oct. 24	14	5,203	6,134	936	18	49	42	5.56	10.48	1.40	11.88
58	do	400	1,163	2.66	Oct. 11 to Oct. 25	15	1,164	1,342	179	15	45	13	6.50	12.16	1.65	13.81
59	do	940	2,686	2.86	do	15	2,735	3,175	489	18	52	23	5.59	10.46	1.42	11.88
60	do	480	1,321	2.75	Oct. 13 to Oct. 27	15	1,397	1,472	151	11	31	15	9.25	17.13	2.32	19.45
61	do	960	2,869	2.99	do	15	2,794	3,109	240	8	25	45	11.64	21.56	2.92	24.48
62	do	1,600	4,833	3.02	Oct. 17 to Oct. 29	13	3,984	5,292	459	10	29	45	8.68	15.83	2.30	18.13
63	do	1,040	3,205	3.08	Oct. 19 to Oct. 30	12	2,423	3,484	279	9	27	25	8.69	15.58	2.27	17.85
64	do	1,680	5,077	3.02	Oct. 20 to Oct. 31	12	3,965	5,725	648	13	39	32	6.12	11.09	1.63	12.72
65	do	1,300	4,203	3.23	Oct. 22 to Nov. 1	11	2,860	4,435	232	6	18	44	12.33	22.75	3.47	26.22
66	do	768	2,534	3.30	do	11	1,690	2,895	361	14	47	8	4.68	8.64	1.32	9.96
67	do	924	3,004	3.25	Oct. 25 to Nov. 3	10	1,894	3,284	280	9	30	.....	6.76	12.90	1.98	14.88
68	do	2,280	7,701	3.38	Oct. 29 to Nov. 4	9	4,264	8,427	726	9	32	38	5.87	11.37	1.76	13.13
69	do	1,060	3,446	3.25	Oct. 30 to Nov. 5	7	1,643	3,843	397	12	38	10	4.14	8.04	1.34	9.38
70	do	512	1,373	2.68	Oct. 30 to Nov. 6	8	906	1,506	133	10	26	2	6.81	13.36	2.35	15.71

71	...do.....	572	1,844	3.22	Oct. 31 to Nov. 6....	7	881	2,036	192	10	34	3	4.59	9.15	1.64	10.79
72	...do.....	1,470	4,862	3.31	Nov. 2 to Nov. 7....	6	1,882	5,324	462	10	31	10	4.07	8.31	1.62	9.93
73	...do.....	1,660	5,600	3.37	Nov. 5 to Nov. 10...	6	2,158	5,899	299	5	18	13	7.22	13.82	3.05	16 87
74	...do.....	1,470	4,762	3.24	Nov. 6 to Nov. 11...	6	1,882	5,088	326	7	22	7	5.77	11.09	2.52	13.61
75	...do.....	768	2,559	3.33	Nov. 7 to Nov. 12...	6	975	2,695	136	5	18	5	7.17	13.66	3.16	16.82
76	...do.....	1,720	5,978	3.48	Nov. 8 to Nov. 13...	6	2,305	6,353	375	6	22	11	6.15	11.60	2.61	14.21
77	...do.....	1,980	6,633	3.35	Nov. 9 to Nov. 14...	6	2,752	7,203	570	9	29	15	4.83	9.34	1.98	11.32
78	...do.....	2,170	7,210	3.32	Nov. 10 to Nov. 17..	8	3,819	7,699	489	7	23	24	7.81	14.60	3.28	17.88
79	...do.....	512	1,758	3.43	Nov. 12 to Nov. 18...	7	799	1,923	165	9	32	3	4.84	8.59	2.02	10.61
80	...do.....	1,020	3,601	3.53	Nov. 13 to Nov. 19...	7	1,561	3,799	198	6	19	12	7.88	13.60	2.99	16.59
81	...do.....	832	2,873	3.45	Nov. 14 to Nov. 19...	6	1,048	3,078	205	7	25	4	5.11	8.57	1.95	10.52
82	...do.....	1,470	5,127	3.49	Nov. 15 to Nov. 20...	6	1,808	5,485	358	7	24	8	5.05	8.38	1.72	10.10
83	...do.....	1,470	5,044	3.43	Nov. 16 to Nov. 21...	6	1,749	5,435	391	8	27	11	4.47	7.45	1.39	8.84
84	...do.....	1,280	4,211	3.29	Nov. 17 to Nov. 22...	6	1,549	4,498	287	7	22	7	5.40	8.87	1.43	10.30
85	...do.....	896	3,281	3.66	Nov. 16 to Nov. 24...	9	1,595	3,523	242	7	27	3	6.59	10.48	1.81	12.29
86	...do.....	660	2,215	3.36	Nov. 17 to Nov. 24...	8	1,049	2,344	129	6	20	2	8.13	12.95	2.05	15.00
87	...do.....	1,270	4,570	3.60	Nov. 19 to Nov. 25...	7	1,816	4,866	296	7	23	11	6.14	9.44	1.33	10.77
88	...do.....	1,070	3,590	3.36	Nov. 22 to Nov. 28...	7	1,616	3,861	271	8	25	5	5.96	8.89	1.38	10.27

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 22

Contribution from the Bureau of Biological Survey, Henry W. Henshaw, Chief. September 16, 1913.

GAME LAWS FOR 1913

A SUMMARY OF THE PROVISIONS RELATING TO SEASONS, EXPORT, SALE, LIMITS, AND LICENSES.

By T. S. Palmer, W. F. Bancroft, and Frank L. Earnshaw,
Assistants, Biological Survey.

INTRODUCTION.

SCOPE OF THE BULLETIN.

The present bulletin, containing the fourteenth annual summary of the game laws of the United States and Canada, has been prepared on the same general plan as those issued each year since 1902. It contains a summary of the more important features of the new legislation, a brief synopsis of the new game laws enacted in each State and Province, and a series of tables showing the provisions relating to seasons, export, sale, limits, and licenses. It differs from other publications on the game laws in several important points: (1) Inclusion of a brief but comprehensive review of the measures enacted, (2) arrangement of provisions by subjects instead of by States, and (3) adoption of a uniform statement and order of the various details to facilitate ready comparison of similar provisions in different States. Its chief objects are to present in convenient form the restrictions on hunting which affect the enforcement of the Federal statutes regulating interstate commerce in game and the protection of migratory birds, and to show the trend and general condition of legislation from year to year. Provisions relating to methods of capture, game refuges, enforcement of laws, disposition of fines and fees, and matters of special or local application are omitted. These can be found only by reference to the laws themselves or to the pamphlet editions of the game laws, obtainable in most States from the proper officials.[1]

[1] A directory of these officers, with their addresses, is published as Circular No. 94, Biological Survey U. S. Department of Agriculture, 1913.

With the rapidly growing complexity of regulations—Federal, State, and local—in 50 States and Territories, and the constantly increasing number of persons who hunt, the demand for information concerning game laws is spreading. The problem of how to keep the public informed of the numerous yearly changes taxes the ingenuity of officials, and can be solved only by the fullest cooperation on the part of the press, private associations, and individuals.

LEGISLATION IN 1913.

The game legislation of 1913, while large in volume, is not much larger than that of 1911 or 1909, owing to the following causes: Codification bills were enacted in Maine, Oregon, and Vermont; practically all the changes made in Illinois, Montana, New York, Utah, Washington, and Wyoming were embodied in single bills; and all legislation failed in Georgia, daho, Nebraska, New Mexico, South Carolina, and Texas.

Legislative sessions were held in 43 States, 8 Canadian Provinces, and Newfoundland. Numerous bills affecting game were under consideration in nearly every State, and regulations for the protection of migratory game and insectivorous birds in the United States and game in Alaska were promulgated by the Department of Agriculture.

NOVEL OR IMPORTANT PROVISIONS.

Among the various provisions found in the new laws are several novel features directly affecting the hunter or the conditions under which game may be hunted:

Ohio and Pennsylvania now require licensees to wear a badge conspicuously exposed, bearing the number of his hunting license. In order to minimize shooting accidents, Manitoba requires hunters to wear a white coat or sweater and cap, and Saskatchewan insists that those who hunt big game must wear a complete outer suit and cap of white. The latter Province has recently made the penalty for accidentally shooting a person a fine ranging from $500 to $1,000, or imprisonment for six months, and suspension of further license privileges for 10 years. To the present list of six States prohibiting the use of silencers—namely, Maine, New Jersey, North Dakota, Washington, Mississippi, and Louisiana—are now added Minnesota and Wyoming. Connecticut has provided that any hunter who shall injure a fence or let down a bar without replacing it shall forfeit his hunting license and the license privilege for two years. Connecticut, Pennsylvania, and British Columbia require license applicants under 16 years of age to furnish the written consent of parent or guardian. Vermont has a similar restriction for those under 15, and Oregon does not permit children under 14 years old to hunt except on the premises of their parents, relatives, or guardians.

An interesting experiment has been undertaken in Utah, where the game commissioner, with the concurrence of the State board of examiners, is authorized to set aside and maintain a public hunting reserve in the counties of Salt Lake, Davis, and Box Elder.

Numerous States are restocking preserves with elk and other big game. In the effort to protect this game Pennsylvania, Vermont, West Virginia, and Wisconsin have protected elk for a term of years, and in Massachusetts, where a few moose have escaped from the Blue Mountain Forest Reserve into the adjoining woodlands, a perpetual close season for moose has been provided in the hope that this area may eventually be restocked from this nucleus.

REFUGES.

One of the marked features of the legislation of the year was the unusual progress in the establishment of bird and game refuges. By Executive order four national bird reserves have been created, the Aleutian Reservation, containing the entire chain of Aleutian Islands, in Alaska, and the smaller reservations of Walker Lake in Arkansas, Petit Bois Island on the coast of Alabama, and Anaho Island in Pyramid Lake, Nevada, thus bringing the total number of national bird reservations up to 64. During recent months the Niobrara Bird Reservation has also been enlarged and stocked with a herd of buffalo, elk, and deer. An item in the act of March 4, 1913, contains an appropriation for the completion and maintenance of the elk refuge in Wyoming.

No less than 18 State game preserves were created, 14 in the United States and 4 in Manitoba. In Washington the county game commissioners were authorized to create game preserves, not to include more than three townships in a county, and the authorities of Michigan, Ohio, and Vermont were authorized to establish game preserves by contract on private lands. The Pennsylvania commission set aside a preserve in Center County for the protection of elk, deer, and other game, and this reservation has already been stocked with a herd of 10 elk secured from a private preserve.

Montana created the Sun River Game Preserve in the Lewis and Clark National Forest; Oregon, the Imnaha, Deschutes, Steen's Mountain, Sturgeon Lake, Capitol, and Grass Mountain Preserves; South Dakota, a preserve in Custer County and appropriated $15,000 for fencing and stocking it; Utah, the Strawberry Valley and Fish Lake State game preserves; Washington, a preserve near Commencement Bay on Puget Sound; and Wyoming modified the boundaries of the Teton and Big Horn preserves and established three new refuges known as the Laramie, Popo Agie, and Shoshone preserves. In Canada, the Riding Mountain, Spruce Woods, Turtle Mountain, and Duck Mountain game preserves were created in Manitoba.

BIG GAME.

Several important changes have been made in provisions protecting big game. Colorado and North Dakota prohibited all killing of deer for a term of years and Saskatchewan has provided a close season throughout the year for all big game south of latitude 52°. Laws protecting does at all seasons were enacted in Florida, Nevada, and Wyoming, but South Dakota repealed a statute of this kind enacted in 1911. The deer seasons were shortened from two weeks to two months in Utah, Wyoming, and Quebec. New Hampshire lengthened the season two weeks in Coos County, Vermont ten days, and Massachusetts opened the season in the few closed counties, thus permitting shooting throughout the State. Montana provided that the limit of three deer a season can include only one doe. In 1911 Michigan made an experiment of an open season of 45 days on deer but limited the life of an individual hunting license to 25 days from date of issuance. After a trial of two years the season has been restored to the last three weeks in November to correspond with the deer season in Minnesota and Wisconsin.

Wyoming and Montana, heretofore affording the principal hunting for elk and sheep, have recently limited the hunting area to a few counties in each State, where the seasons have generally been shortened. Wyoming has adopted the innovation of allowing the killing of female elk only under ordinary resident licenses and requiring licensees to obtain a special $15 license to kill a bull or an additional cow. Montana also prohibited the killing of ewes and lambs. Other States in which elk or sheep were protected for a term of years or by a perpetual close season are Nevada, Oregon, Utah, and Washington.

OPEN SEASONS.

The most important changes in seasons are due to the passage of the Federal law protecting migratory birds. Under the regulations as proposed by the Department of Agriculture (see pp. 20–21), spring shooting is entirely eliminated and the open seasons materially shortened in several States.

The general trend of State legislation in the matter of seasons seems to have been toward further restriction of hunting and greater uniformity. This fact is illustrated by the enactment of the general game law in Florida, which repealed all local game laws and made the seasons uniform throughout the State, and the passage of a measure in Wisconsin adopting the same opening date for upland game as is in force in Minnesota and North Dakota. A few important species were removed from the game list or were given protection for

a term of years. New York placed a close season on quail for five years and Kansas added both quail and prairie chickens to the close-season list until 1918. Ohio suspended hunting of quail, ruffed grouse, and doves for two years, Pennsylvania eliminated the open season on doves, killdeer plover, and blackbirds, while Utah extended complete protection to doves, swans, and all shore birds except snipe.

Among the notable examples in the curtailment of open seasons may be mentioned the following: Delaware shortened the season on ducks a month and on geese two weeks; Indiana curtailed the season six weeks on doves and 10 days on quail and ruffed grouse; Michigan, 16 days on woodcock; and Missouri, one month on quail; Oregon shortened the season 45 days on doves and pigeons, six weeks on shore birds, rail, and geese, and west of the Cascades curtailed the season on ducks 17 days. New Jersey shortened the open season 26 days on upland game and 19 days on woodcock, while Pennsylvania cut down the woodcock season two weeks. In Utah, 45 days were taken off the open season on sage hens and in Wyoming one month on sage grouse and two months on ducks and geese.

At least six States passed laws lengthening open seasons. Illinois added a week for hunting prairie chickens; Michigan, 15 days for ruffed grouse and spruce hens, and 45 days for shore birds and rail; Oregon, 16 days for ducks east of the Cascades; and Vermont, 16 days for ruffed grouse and woodcock and two weeks for plover.

In California several changes in seasons were caused by transfer of certain counties from one game district to another. In this transfer a peculiar condition arose in San Joaquin County. The open season on deer in this county began July 1, as in other counties in District No. 4, but on August 11 the new law went into effect transferring the county to District No. 3, where the open season for deer did not begin until August 15. Consequently the season was closed for three days, August 12, 13, and 14, but opened again on the 15th and continued until October 31. These district changes also account for several differences in the open seasons for doves and quail.

EXPORT AND SALE.

The restrictions on native wild game have a tendency to increase, while those on game imported into the United States or raised in captivity or on private preserves are becoming more liberal.

The sale of imported game was permitted or facilitated in Colorado, Montana, New Jersey, Oregon, and Wyoming, while Arizona repealed the provision permitting the sale of imported game by hotels and restaurants.

The industry of rearing game in private preserves received impetus in the form of legislation permitting the sale of game raised in cap-

tivity in Minnesota, New Jersey, and Oregon, but Maine repealed the provision permitting sale of game raised in private preserves.

The sale of all protected game was prohibited in Nevada, Oregon, and Wyoming, while New Jersey enacted provisions similar to those of the New York law prohibiting the sale of all game belonging to a family any species or subspecies of which is native to and protected by the State law.

Other interesting sale provisions are the continued suspension of sale of deer in southeastern Alaska until August 15, 1914, and the prohibition in Pennsylvania of the sale of quail and ruffed grouse wherever taken.

Michigan permitted transportation and sale of rabbits lawfully killed and the sale and export of deerskins or green or mounted buck deer heads under permit; while Vermont permitted deer to be sold during the open season and for a "reasonable time thereafter" and rabbits during the open season.

The legislation of the year shows a decided tendency to place more stringent restrictions on the export of native game. Wyoming prohibited the export of all protected game; Maine reduced the export limit of partridges under a resident license tag from 6 to 5; Ohio reduced the export limit under a nonresident license from 50 to 25 birds and animals, while Maine increased the export limit on ducks under nonresident license from 10 to 15, and permitted a nonresident to export one pair of game birds a month under a 50-cent tag; Michigan restored the provision permitting a nonresident to export one deer under permit and license, and New York required nonresidents to obtain permits to export deer.

BAG LIMITS.

The changes in bag limits tend as usual toward further restrictions. Some novel features in weekly limits were enacted in the Northwest, where in an effort to forestall large week-end bags of birds, Washington provided that the week should end at midnight Wednesday night, and Oregon provided limits for seven consecutive days.

In the case of big game, Washington reduced the limit on sheep and goats from two to one each, and Wyoming now permits only one female elk under each ordinary resident license. In the case of deer, Florida and Oregon reduced the limits from five to three; Montana provided that the limit of three deer shall not include more than one doe; Wyoming reduced the number of deer from two to one, and Maine from two to one in Androscoggin County.

With these restrictions, deer hunting, as shown in the accompanying map, is now permitted in 36 States, 12 of which limit the hunter to one deer a season, and 10 to two. In only about a quarter of the

States is the limit three or more. In Florida, Georgia, Montana, Oregon, and Texas, three; in Louisiana, Mississippi, and South Carolina, five; in Alaska, six; in Alabama and Missouri, one a day; and in Kentucky, Virginia, Arkansas, and North Carolina, no limits except in a few counties in the last two States.

In the case of small game, Vermont reduced the limit on rabbits from six to five a day, and Long Island placed a limit of six a day on varying hares and cottontails.

Among the important reductions in bag limits on birds may be mentioned Missouri, which reduced the daily limit from 25 to 10 and the limit allowed in possession at one time from 50 to 15. Vermont reduced the limit on ruffed grouse, partridge, and woodcock from

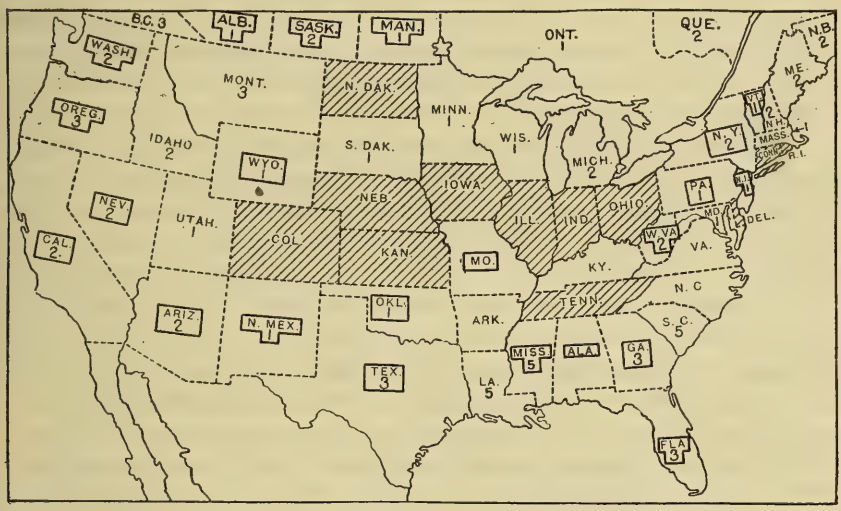

FIG. 1.—States and Provinces permitting deer hunting in 1913.

[In the shaded States there is no deer hunting. Figures indicate the number of deer allowed each hunter a season. In the eastern half of Maine and the southern half of New Hampshire, the limit is one a season. In Alabama, Mississippi, and Missouri, the limit is one a day, and in Louisiana, two. In Arkansas and North Carolina limits are provided in a few counties only. No limits are provided in Kentucky and Virginia. Inclosed names indicate the States which protect does at all seasons.]

5 to 4. In Delaware the limit on rail was reduced from 75 to 50 a day, plover from 15 to 5, and sandpipers from 75 to 50. Washington, while repealing the daily limit on waterfowl, reduced the weekly limit from 50 to 20, and on upland game birds from 30 to 25. Wyoming increased the daily bag limit on geese only from 5 to 12. In Canada, Saskatchewan established limits of 50 a day and 250 a season on waterfowl. In new bag limits, Long Island provided a limit of 10 quail a day—50 a season; and 4 ruffed grouse a day—20 a season; while Utah established limits of 6 a day, and 25 a year on grouse.

LICENSES.

License measures received consideration in 16 States and 4 Canadian Provinces, and resident licenses were adopted for the first time in Delaware, Florida, Michigan (birds), Ohio, and Pennsylvania. The fee in each instance is $1 with additions of 10 to 25 cents as a clerk fee in Delaware, Ohio, and Pennsylvania. Alberta also required a $1.25 bird license for residents of cities in the southern part of the Province. Other new license requirements were as follows: Maine provided a special nonresident license (fee $5) for hunting birds in certain counties prior to October 1; Michigan a nonresident and resident alien license (fee $10) for small game; Wyoming withdrew the privilege permitting a nonresident to be afield with a .22-caliber rifle without a license; and Alberta required a resident big game license throughout the Province, but the fee to farmers and their sons residing on their own land was reduced to $1. License fees were increased in several States. In Vermont the resident license was raised from 50 to 75 cents; the Maine general nonresident license from $15 to $25; in Montana the general alien from $25 to $30; and in Wyoming the special resident license permitting the killing of one additional elk from $5 to $15. In Canada resident big game licenses were increased from $2 to $3 and from $2 to $5, respectively, in New Brunswick and Saskatchewan. Fees were also reduced in three Western States: in Utah the cost of the alien license was reduced from $100 to $15; in Wyoming, the alien bird license, from $20 to $5, and the resident bird license from $1.50 to $1; and in Washington the $5 nonresident county licenses and the $50 nonresident alien licenses were abolished.

Montana and Oregon required $25 alien gun licenses in addition to the prescribed hunting licenses, but on the whole the license legislation affecting aliens has been more favorable than usual.

Among the miscellaneous provisions the following may be mentioned: Massachusetts, Wisconsin, and Wyoming strengthened their license laws; New Hampshire authorized town clerks to issue resident licenses, but in order to prevent fraudulent issue of such licenses to nonresidents prohibited issue to any applicant not personally known to the clerk as a resident of the State.

WARDEN SERVICE.

The warden service of at least 17 States was affected either directly or indirectly by the legislation of the year and in most instances the tendency was to increase its effectiveness. Florida created the office of fish and game commissioner, Maine delegated the protection of game on the islands in the sea and 1 mile inland on the coast

to the department of sea and shore fisheries, Wyoming authorized the appointment of employees of the department of agriculture as deputy game wardens without bond or salary, and Wisconsin authorized the State warden to assign deputies for educational work in regard to fish and game. The service has been reorganized in several States. In Montana, South Dakota, and Illinois commissions, instead of single officers, were formed in charge of the work of game preservation; in Ohio an agricultural commission was established to replace several State departments and the game warden department placed under its charge; in Connecticut the personnel of the fish and game commission was increased to include a member from each of the eight counties of the State, while New Hampshire was the only State which abolished its fish and game commission and placed the work in charge of a single officer. Delaware established the resident and nonresident license system, thus providing funds for the operation and maintenance of the game commission created in 1911. Arkansas, Mississippi, Nevada, and Virginia are now the only States which have no State officials in charge of the work of game protection.

Increase in salaries of game officials were granted in several States. In Arizona the compensation of the warden was increased from $1,200 to $1,800, with an allowance of $1,000 for traveling expenses; in Iowa from $1,600 to $2,200; in Utah from $1,800 to $2,400; in Wisconsin from $2,000 to $2,500; and in Illinois the president of the commission was given $4,000. Deputies were also provided for in some cases. Arizona created the position of office deputy at a salary of $1,200, provided that warden salaries and expenses should be paid from the general fund of the State, and authorized the appointment of such per diem deputies as might be necessary. Vermont appropriated $2,500 for clerical assistance for the biennial period, and Utah increased the salary of the chief deputy from $1,200 to $1,400, Washington from $1,500 to $1,800, and Wyoming authorized the appointment of a clerk in the warden department at $1,200 a year and increased the compensation of county wardens from $3 to $5 per day. Iowa authorized the appointment of three assistant game wardens at $1,200 per annum each; North Dakota increased the warden force by authorizing the appointment of one regular deputy for each judicial district instead of four for each commission district, while South Dakota provided for the appointment of three salaried wardens and five assistant per diem game wardens in lieu of the former county wardens. In Oklahoma the salaried warden system of 12 deputies was abolished, thus limiting the service to assistant wardens, who serve on a fee basis and without other compensation.

RETROGRADE LEGISLATION.

Among the retrograde legislation of the year may be mentioned the Colorado provision extending spring shooting, the repeal of the Massachusetts provision allowing dogs chasing deer to be killed, the Maine prohibition of sale of game raised in private preserves, the suspension of salaried warden service in Oklahoma, and the repeal of the South Dakota doe law. Game protection funds were diverted to other purposes in New Hampshire by a provision that the surplus shall be devoted to screening ponds and forestry work, and in Florida by the requirement that funds in excess of $5,000 on March 1 of each year shall be turned over to the State school fund.

More than the usual number of game laws have been the subject of vetoes, notably in Wisconsin, where a bill prohibiting aliens from hunting failed to receive the approval of the governor, and in California, where two bills removing the band-tailed pigeon and certain shore birds from the game list were vetoed. The only law apparently in which the referendum was invoked was the California statute prohibiting the sale of game but allowing sale of ducks in November.

PRESENT CONDITION OF GAME LEGISLATION.

As an illustration of the progress of game legislation and the general adoption of certain provisions in the various States, a comparison may be made between conditions in 1900 (the date of the passage of the Lacey act, the first Federal law) and those of to-day. Every one of the 48 States now prescribes seasons for hunting, prohibits export of game, and requires nonresidents to secure a license. Only one State is without some restriction on sale of game, 4 are without State game wardens or commissioners, 5 have no general bag-limit laws, 9 do not issue resident hunting licenses, and 9 have not yet adopted the so-called "model law" for the protection of nongame birds. The progress in each of these features is shown by the following table:

Table showing condition of game legislation in 1900 and 1913.

Provisions.	Number of States.		States lacking legislation.
	1900	1913	
Seasons	48	48	
Export	41	48	
Nonresident license	15	48	
Sale	28	47	(1) North Carolina.
State warden	31	44	(4) Arkansas, Mississippi, Nevada, Virginia.
Limits	20	43	(5) Arkansas, Kentucky, North Carolina, Rhode Island, Virginia.
Resident license	5	39	(9) Arkansas, Maine, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia.
Nongame birds (model law)	7	39	(9) Arizona, Idaho, Kansas, Maryland, Montana, Nevada, Nebraska, New Mexico, Utah.

NEW LAWS PASSED IN 1913.

FEDERAL LAWS.

Two acts: Agricultural appropriation act containing provisions for Federal protection of migratory birds and for the establishment and maintenance of elk refuge in Wyoming (37 Stat., 847); resolution authorizing the President to propose to Governments of other countries the negotiation of a convention for the protection and preservation of birds (S. Res. 25.)

FEDERAL REGULATIONS.

Proposed regulations of the Department of Agriculture under the law for the protection of migratory birds (Biol. Circ. 92); regulations of August 1 under the Alaska game law suspending the sale of deer in Alaska until August 15, 1914, and shortening the season on mountain goats.

STATE LAWS.

Arkansas.—Four acts: Affecting Boone, Calhoun, Grant, Hot Spring, Lonoke, and Monroe counties (Acts 251, 267, 276, 280).

Arizona.—One act: Prohibiting the importation of game for sale; repealing the provision authorizing the State warden to appoint per diem State deputies; increasing the salary of the State warden from $1,200 to $1,800, allowing $1,000 per year for traveling expenses, and authorizing the appointment of an office deputy at $1,200 per year, all to be paid from the general fund; making sheriffs, constables, and live-stock sanitary inspectors ex officio game wardens; authorizing the State warden to appoint such county deputy game wardens as may be necesssary at $3 per diem and expenses while under directions from the State warden.

California.—Several laws; not received at date of going to press.

Colorado.—Two acts: Protecting deer until 1918 and imported pheasants until 1924; lengthening the open season on waterfowl, cranes, and shore birds (except curlew and yellowlegs) 81 days, and on curlews and yellowlegs 112 days; shortening the season on doves two weeks and making it uniform throughout the State (ch. —); memorializing Congress to enact Senate bill 6497 for the protection of migratory game and insectivorous birds (H. J. M. No. 3).

Connecticut.—Six acts: Providing that any licensed hunter who shall injure fences or let down bars without replacing them shall forfeit his hunting license and the privilege of securing another license for a period of two years (ch. 37); shortening the season on rabbits three weeks, making it open on the same date as the season for upland game (ch. 74); prohibiting use of snares for all game (ch. 79); requiring applicants for hunting license to be 16 years old (ch. 103); permitting killing of the starling, and red-winged and crow blackbirds when destroying corn (ch. 133); providing for the appointment of a nonpartisan commission of eight members, one from each county, and the appointment of a superintendent of fisheries and game (ch. 228).

Delaware.—Seven acts: Providing resident and nonresident hunting licenses with fees of $1.10 and $10.50, respectively (ch. 152); closing the season indefinitely on Hungarian partridges, pheasants (ch. 156), and swans in the State and on doves in Newcastle County and reducing the daily limit on rail from 75 to 50 (ch. 158); shortening the seasons on squirrels two months, on ducks one month, and on geese and brant two weeks, and making the season on waterfowl uniform in the State (ch. 159); authorizing the appointment of a chief game and fish warden, salary $600 per annum (ch. 153); providing that all fines shall be paid into the game protection fund

(ch. 154); increasing the weekly export limit on birds from 1 dozen to 20 and on animals from 6 to 10 of each species and repealing the shipping exemption in favor of residents on plover, snipe, and ducks; requiring officers of any court to remit fines collected to the commission, and abolishing the informer's fee and the provision that part of the fines shall go to the Audubon Society (ch. 155).

Florida.—Three acts: A general game law, making seasons on all game uniform throughout the State, prohibiting the killing of does and hen turkeys at any time and ruffed grouse and imported pheasants until December 1, 1915; prohibiting export and sale of all protected game, reducing the bag limit on deer from five to three a year, providing daily and yearly limits on birds, and repealing all local laws (ch. 6534); creating the office of game and fish commissioner at a salary of $2,500 and establishing $1 county and $3 State licenses for residents and a $15 county license for nonresidents and aliens, creating a game and fish protection fund and providing that any surplus above $5,000 in said fund shall be paid March 1 each year into the State school fund (ch. 6535). Extending absolute protection to robins (ch. 6533). A number of local game laws were passed but were all repealed by the provision in ch. 6534.

Georgia.—No legislation.

Idaho.—No legislation.

Illinois.—One act: Replacing the office of State game commissioner by a State game and fish conservation commission of three members, the president to receive a salary of $4,000, the other two members $3,000 each; authorizing the appointment of six wardens at $1,500 and 60 deputy wardens at $1,200 a year each, and additional deputies for temporary services at $100 per month; shortening the open season on squirrels one month and on doves six weeks; lengthening the season on prairie chickens one week; extending the close term until 1918 on partridge, blue, mountain, and valley quail, Hungarian partridge, capercailzie, heath hen, black grouse, and woodcock, and until 1923 on wild turkey, sand grouse, and imported pheasants and partridges; and providing that all license receipts shall be paid into the State treasury (S. B. 617).

Indiana.—Four acts: Prohibiting the use of ferrets in hunting rabbits (ch. 12); repealing the provision requiring one-third of the license receipts to be expended for restocking purposes and providing that all license receipts shall be paid into a fish and game fund (ch. 120); shortening the open season on quail and ruffed grouse 10 days, extending protection to rabbits from January 10 to April 1, and prohibiting the hunting of any other game from December 20 to April 1; reducing the commissioner's fee taxed against the defendant under the game laws from $20 to $5 (ch. 147); removing protection from blackbirds and increasing the maximum penalty for violation of the nongame bird law from $25 to $50 (ch. 197).

Iowa.—Two acts: Increasing the salary of the game warden from $1,600 to $2,200 and authorizing the appointment of three assistant game wardens at $1,200 a year each (ch. 203); providing that no deer shall be distrained until it shall be necessary in the opinion of the game warden or his deputies (ch. 206).

Kansas.—Two acts: Protecting quail and prairie chicken for five years, adding doves to the game list without a season, but providing a limit of 20 a day; increasing the limit on plover and ducks from 12 each to 20 each a day (ch. —); authorizing the issue of permits to export game birds for scientific or propagating purposes (ch. —).

Maine.—One act: General revision and codification of game and fish laws; shortening the season on bull moose two weeks; protecting deer on Mount Desert Island, shifting the season in Androscoggin County, and making it more uniform in the State; repealing the provision authorizing the commission to reimburse farmers and tenants for damage done by deer; extending complete protection to Hungarian partridges; pheasants, black game, and capercailzie, (cock of the woods); making the law on ducks uniform throughout the State; reducing the daily bag on plover from 15 to 5. on

snipe and ducks from 15 to 10, and on sandpipers from 70 to 50; removing protection from the mudhen (bittern), kingfisher, loon, and blue heron; increasing the fee for a nonresident general license from $15 to $25, and providing special $5 licenses for hunting birds prior to October 1 and November 1 in certain parts of the State; increasing the export limit of ducks under a nonresident license from 10 to 15; permitting nonresident licensee to export one pair of game birds a month, unaccompanied, under a 50-cent tag; making the appointment of inland deputies expire with the calendar year in which made; prohibiting the sale of game raised in private preserves; and extending the jurisdiction of the department of sea and shore fisheries to all islands along the coast of the State and to a distance of 1 mile inland, including all bays and inlets so far as the tide ebbs and flows except on the Kennebec River above the city of Bath (ch. 206).

Massachusetts.—Nine acts: Strengthening the license law (ch. 249); shifting the season on gray squirrels to make it uniform with that on upland game birds (ch. 270); authorizing city and town councils to protect insectivorous birds and to appoint bird wardens (ch. 296); extending the license exemption in favor of certain nonresident taxpayers to their minor children over 18 years of age (ch. 479); opening the season throughout the State on deer (ch. 529); prohibiting the use of rifle, revolver, or pistol for hunting any game (ch. 542); providing a penalty of $20 for knowingly permitting a dog to chase deer (ch. 552); prohibiting the poisoning and snaring of wild animals (ch. 626), and extending protection to moose throughout the year (ch. 744).

Michigan.—Eight acts: Protecting the snowy heron and prohibiting sale of its plumage (No. 22); removing protection from black bears (No. 83); prescribing $1 resident and $10 nonresident licenses for small game (No. 108); permitting the transportation and sale of rabbits lawfully killed, and sale and export of deer skins or green or mounted buck deer heads under permit; reducing the daily bag on plover from 10 to 6; shortening the season on deer 23 days, and on woodcock 16 days; extending the close term on squirrels to 1915, and that on quail, English and Mongolian pheasants, black game, capercailzie, hazel grouse, and wild turkeys to 1917; lengthening the season on rabbits 45 days, on ruffed grouse and spruce hens 15 days; on ducks, snipe, plover, shorebirds, and sora rail 45 days; and on coots and other rail one month, and permitting nonresident licensees to export one deer under permit (No. 167); establishing a game preserve on the new maneuvering grounds of the State militia in Crawford County (No. 172); increasing the salary of the chief deputy from $1,500 to $1,800, providing for the appointment of deputies at salaries from $2.50 to $4 a day, with promotions on a merit basis after examination (No. 313); amending form of deer licenses and affidavits and requiring licenses to be issued in stated distinctive colors (No. 328); and authorizing the establishment of game preserves on private holdings and State forests (No. 360).

Minnesota.—Eight acts: Repealing the law prohibiting the use of ferrets for rabbits in certain counties (ch. 5); prohibiting the use of silencers (ch. 64); protecting game on lands designated by commission as game propagating and breeding grounds (ch. 95); permitting game birds to be raised in captivity under permit and sold when properly tagged (ch. 131); protecting squirrels on all public grounds and within one-quarter mile thereof (ch. 133); prohibiting shooting of waterfowl from one hour after sunset to one hour before sunrise (ch. 212); permitting big game raised in private preserves to be killed and sold at any time under permit (ch. 485); memorializing Congress to afford protection to migratory game bids (J. Res. No. 13).

Missouri.—Four acts: Shortening the season on quail one month (p. 346); on squirrels three weeks (p. 347); reducing the daily limit on birds from 25 to 10 and the number allowed in possession at one time from 50 to 15 (p. 348); and prohibiting the use of dogs for hunting deer (p. 346).

Montana.—Eight acts: Making all licenses expire on April 30 of each year (ch. 31); protecting elk until 1918 except in certain counties, and prohibiting the killing of fawns, ewes, and lambs (ch. 33); establishing the Sun River Game Preserves in Lewis and Clark National Forest (ch. 34); requiring certain aliens to obtain a $25 gun license (ch. 38); classifying hunting and fishing licenses; increasing the fee of an alien general license from $25 to $30; creating the Montana game and fish commission to consist of the State warden, and four unsalaried members appointed by the governor, term four years; permitting common carriers to transport fish, game, and birds for restocking, and agents of State or Federal Government prosecuting such work in the State free of charge or at reduced rates, and providing that not more than one doe shall be included in the limit of deer (ch. 79); authorizing the appointment of six additional special deputy game and fish wardens, at a salary of $1,500 a year each with expenses not to exceed $900 a year (ch. 96); permitting merchants, hotel, or restaurant keepers to sell under transportation receipt game that has been killed outside the State (ch. 100); defining the term "sale" of game and fish (ch. 126).

Nebraska.—No legislation.

Nevada.—Four acts: Authorizing board of county commissioners, upon receipt of petition of 25 residents, to open the season on sandhill crane, shore birds, and waterfowl September 1 (ch. 78); prohibiting sale of all protected game except sandhill crane and swan (ch. 241); protecting mountain sheep and goats until 1920 (ch. 252); shortening the season on grouse two weeks, shifting the season on deer to open a month later and prohibiting the killing of does, and authorizing county commissioners upon petition to change and shift open seasons (ch. 265).

New Hampshire.—Four acts: Lengthening the open season on deer two weeks in Coos County (ch. 63); making it unlawful to allow self-hunting dogs to run at large between April 1 and October 1 in woods or fields inhabited by game (ch. 143); replacing the board of fish and game commissioners by a single commissioner in charge of game and fish preservation at a salary of $1,800 per annum and reducing the term of office from five to three years; authorizing the biennial appointment of one deputy in each county at a compensation of $3 and expenses for each day of actual service; reducing the fee for issuing resident hunting licenses from 25 to 10 cents; providing that any surplus from the proceeds of fines and hunting licenses shall be devoted to screening ponds and to forestry work (ch. 165); extending the protection on gray squirrels until 1919, but permitting shooting during the month of October outside thickly settled parts of cities and towns (ch. 174).

New Jersey.—Seven acts: Prohibiting the hunting of wild fowl from any sand bar not covered with water (ch. 73); shortening the season on upland game 26 days (ch. 120); permitting the sale under tags of game raised in preserves (ch. 135); permitting certain pheasants, ducks, and deer to be raised in inclosed preserves under license (ch. 147); authorizing game commissioners and protectors to file complaints on "information and belief" (ch. 148); prohibiting use of hounds in hunting except during the open season for quail (ch. 157).

New Mexico.—No legislation.

New York.—One act: Lengthening the season on varying hares and rabbits one month; shifting the season on squirrels; closing the season on quail until 1918; shortening the season one month on varying hares and cottontail rabbits on Long Island; permitting nonresident licenses to export one deer under permit; permitting game raised in captivity to be killed and sold at any time under license; providing the following bag limits for Long Island, 10 quail, 4 ruffed grouse, and 6 varying hares or cottontail rabbits a day, 50 quail, and 20 ruffed grouse a season; and making numerous technical amendments to the conservation law (ch. 508).

North Carolina.—Numerous local laws; not received at date of going to press.

North Dakota.—One act: Authorizing the appointment of one regular deputy warden for each judicial district (instead of four for each commission district); closing the season on deer until 1916, prohibiting spring shooting of geese and cranes, and adding all the year protection to partridge.

Ohio.—Three acts: Removing quail, ruffed grouse, and doves from the game list by closing the season until 1915; extending the protection on imported pheasants to 1915; closing the open season on shorebirds, rails, coots, and waterfowl December 1 (No. 79); creating the agricultural commission and delegating to it the work of game preservation (No. 147); providing a resident license, fee $1.25, and requiring licensee to wear a badge conspicuously exposed bearing the number of his hunting license; creating a game-protection fund into which all license receipts shall be paid; authorizing the expenditure of 50 per cent of the game fund for the purposes of restocking, and the establishment of game preserves on private holdings; and reducing the export limit under a nonresident license from 50 to 25 birds or animals (No. 249).

Oklahoma.—Two acts: Opening the season on male deer in Delaware County (ch. —); abolishing the salaried-warden system and the present force of 12 wardens.

Oregon.—Five acts: General revision of the game and fish laws—Dividing the State into two game districts, east and west of the Cascades; extending absolute protection to elk, caribou, and goats; affording protection throughout the year to imported pheasants and partridges, bobwhite, prairie chicken, wild turkey, certain shore birds, and swan; shortening the season on doves and wild pigeons 46 days, on shore birds, rail, coot, and geese 6 weeks, and on ducks west of Cascades 17 days, but east of Cascades lengthening the season 16 days; protecting squirrels east of Cascades all the year; reducing the limit on deer from 5 to 3; making numerous changes in local bag limits; providing limits for seven consecutive days instead of individual weekly limits; prohibiting the sale of all game, except imported game, between September 1 and November 1, and game birds or animals raised in captivity under permit and tag; establishing civil liability for game illegally killed; providing a $25 alien gun license; permitting game to be raised in captivity under permit; removing protection from cormorants, American mergansers, and ravens, and prohibiting use of a gun larger than 10 gauge (ch. 232); creating the Imnaha, Deschutes, Steen's Mountain, Sturgeon Lake, Capitol, and Grass Mountain game preserves (ch. 189); permitting such exceptions in contracts for the establishment of game preserves on private lands as will protect the property or crops of the owner (ch. 251); resolution requesting Federal protection of migratory game birds (S. J. M. No. 2); resolution requesting enactment of a law establishing Federal refuges for the protection of big game (S. J. M. No. 6).

Pennsylvania.—Seven acts: Removing doves, killdeer plover, and blackbirds from the game list (No. 11); protecting elk until 1921, but permitting them to be raised in captivity under the same regulations as apply to deer (No. 26); prescribing a resident license, fee $1.15, and requiring each licensee to wear the number of his license on back of his sleeve (No. 63); shifting the season on squirrels, ruffed grouse, and imported pheasants two weeks earlier; shortening the season on woodcock two weeks, lengthening the season on rabbits and Hungarian partridges two weeks (No. 70); amending the nongame bird law by extending protection to the shrike, eagle, osprey, crane, heron, bittern, and raven, and prohibiting the sale of plumage of native birds or any foreign birds of the same family, in effect July 1, 1914 (No. 72); protecting wild turkeys until 1915 (No. 123); prohibiting the sale of quail and ruffed grouse wherever taken (No. 134).

Rhode Island.—One act: Shifting the season on quail, ruffed grouse, and woodcock two weeks, to open November 1 instead of October 15, and protecting imported pheasants and Hungarian partridges until 1920 (ch. 966).

South Carolina.—No legislation.

South Dakota.—Five acts: Creating a State game and fish commission to consist of the governor, attorney general, and the State game warden, and providing for the employment of one clerk, three assistant salaried wardens, and five assistant per diem game wardens (supplanting the county game-warden system), and providing rewards for informers (ch. 223); establishing a State game preserve in Custer County and appropriating $15,000 for fencing and stocking it (ch. 224); extending absolute protection to quail (ch. 225); creating a game fund (ch. 226); repealing the protection afforded does in 1911 and permitting them to be killed during the regular open season (ch. 227).

Tennessee.—Four local laws: Protecting game in Haywood, Johnson, Lauderdale, Washington, and Unicoi Counties (chs. 117, 269, 271, 309).

Texas.—No legislation.

Utah.—Two acts: General revision of the game laws: Increasing salary of the commissioner from $1,800 to $2,400 and that of the chief deputy from $1,200 to $1,400 per annum; shortening the season two weeks on deer, 45 days on sage hens, on quail in certain counties, and providing an open season of 10 days on grouse and a limit of 6 a day and 25 a year; providing a close season throughout the year for elk, antelope, sheep, doves, shore birds (except snipe), and swans; increasing the daily limit on geese from 5 to 12; affording protection throughout the year to pelicans, bitterns, hawks, blackbirds, and kingfishers; reducing the fee for an alien license from $100 to $15; creating the Strawberry Valley and Fish Lake game preserves; authorizing the commissioner with concurrence of the State board of examiners, to set aside and maintain public hunting grounds in Salt Lake, Davis, and Box Elder Counties (ch. 46); and providing for the observance of bird day in the schools on the last Friday in April of each year (ch. 60).

Vermont.—Five acts: General revision and codification of the game laws; lengthening the season on deer 10 days, on ruffed grouse and woodcock 16 days, and on plover and English snipe two weeks; providing a close season on other shore birds for the first time, December 1 to September 1, and providing no open season for pheasants, European partridges, upland plover, and wood duck; permitting the sale of deer and rabbits during the open season and of deer for a "reasonable time thereafter;" increasing the resident license fee from 50 to 75 cents; reducing the daily bag on rabbits from 6 to 5 and limiting possession of rabbits and squirrels to one day's bag; reducing the daily limit on quail, ruffed grouse, partridge, and woodcock from 5 to 4 each, and that on plover and English snipe from 5 each a day to 10 of all shore birds combined; authorizing the commissioner to seize and confiscate birds or quadrupeds held in violation of law, and wardens to search without warrant; providing for the establishment of private preserves, game refuges, and regulation of propagation farms (No. 201); relating to rabbits (No. 205); trapping and other prohibited methods of taking game (No. 206); protecting elk for 10 years (No. 208); appropriating $2,500 for clerical assistance of the commissioner for the biennial period (J. Res. No. 496).

Washington.—Three acts: Creating a county game commission of three resident members for each county and providing for the appointment of a chief game warden west of the Cascades and a chief deputy warden east of the Cascades; county commission authorized to appoint wardens and assistants and to set aside by proper publication county game preserves; shifting the season on big game to open October 1 instead of September 1; protecting moose until 1925, and allowing no open season for caribou and swan, with numerous changes in local seasons, tending slightly toward uniformity; reducing the seasonal limit on sheep and goat from 2 to 1 each, and on upland game birds from 30 a week to 25; omitting the daily limit on waterfowl, reducing the weekly limit from 50 to 20, and defining a week to begin at midnight on Wednesday night; repealing the nonresident $5 county license and the $50 alien license (ch. 120); creating a game refuge in Pierce County, near Commencement Bay, on Puget Sound (ch. 122).

West Virginia.—One act: Protecting elk until 1928 (ch. 27).

Wisconsin.—Nineteen acts: Reimbursing the warden and deputies for certain expenditures incurred in the line of duty (chs. 19, 24, 29, 498, and 499); extending absolute protection to deer in Door, and in Wood County until 1916 (ch. 46); permitting use of ferrets for taking rabbits on hunter's own land in Door County (ch. 71); authorizing the prosecution of educational work in behalf of fish and game by the game warden and his deputies (ch. 73); more clearly defining the term "nighttime," during which wild fowl are protected as the period from one hour after sunset to one hour before sunrise central time (ch. 97); granting a clerk fee of 10 cents for issuing resident licenses (ch. 172); permitting shipment or export to a taxidermist of green deer heads when severed from the carcass, under permit from warden (ch. 258); directing superintendent of public property to provide suitable quarters for the warden department (ch. 369); regarding local protection of rabbits and squirrels (chs. 403 and 104); strengthening the license law (ch. 424); authorizing the printing of 3,000 copies of the report of the State fish and game warden (ch. 429); making the seasons for game birds open on the same dates as those in Minnesota and North Dakota (ch. 737); protecting elk indefinitely (ch. 748); and memorializing Congress to set aside unoccupied and unclaimed islands in the Great Lakes for bird reserves (J. Res. 63–A).

Wyoming.—One act: General revision; enlarging powers of game warden and deputies, permitting employees of the U. S. Department of Agriculture to be appointed deputy game wardens without bond or pay; extending term protection to quail and Mongolian pheasants until 1915; shortening the season on deer 2 months, on grouse 4 days, and on sage grouse 1 month; extending term protection to moose, elk, and sheep until 1918, except in three counties in the northwest part of the State, where the season on elk and male sheep was shortened 15 days; repealing the provision permitting nonresidents to be afield with a .22-caliber rifle without a license; reducing the fee for the alien bird license from $20 to $5; prohibiting the sale or possession of game taken in a State, nation, or foreign country when such acts are prohibited in this State; requiring soldiers and sailors stationed at Government posts in the State when hunting to be accompanied by a qualified guide; reducing the clerk fees for issuing licenses; regulating sale and export; modifying the boundary lines of the Teton and Big Horn game preserves and creating the Popo Agie, Shoshone, and Laramie game preserves; increasing the pay of county deputy game wardens from $3 to $5 a day; increasing the fee for a resident special license for one additional elk from $5 to $15; and reducing the fee for a resident bird license from $1.50 to $1; reducing the limit on deer from two to one male, and under a resident ordinary license from two elk to one female elk; authorizing the appointment of a clerk in the office of the State warden at a salary of $1,200; reducing the daily limit of grouse from 12 to 6; and prohibiting the use of a silencer (ch. 121).

CANADIAN LAWS.

Alberta.—One act: Protecting elk until 1915; permitting the sale of all game birds except those of the grouse family September 20 to March 1; making the resident big game license apply throughout the Province, but requiring a fee of only $1 of farmers and their sons residing on their own land; reducing the fee for a market hunter's license from $10 to $5; prescribing a $1.25 bird license for residents of city or town south of township 59; permitting treaty Indians to hunt without license.

Manitoba.—One act: Permitting all game except pheasants to be taken at any time north of latitude 54° by persons in actual need of food; prohibiting hunting of waterfowl in yachts or launches propelled by steam, gasoline, or electric motive power; also protecting waterfowl on sand bars or shallow islands in open waters of Whitewater Lake; prohibiting export of big game except by nonresident licensee, lawfully killing same, under permit, fees, deer $2, and moose, elk, and caribou, $5; creating Riding Mountain, Spruce Woods, Turtle Mountain, and Duck Mountain game preserves, and

prohibiting all hunting on said preserves except that ducks and geese may be taken during the month of October on Turtle Mountain preserve; and requiring persons hunting big game to wear a white coat or sweater and cap (ch. 21).

New Brunswick.—One act: Shortening the season two weeks on snipe; repealing the provision permitting residents of Grand Manan Parish, Charlotte County, to kill black ducks until May 1; prohibiting the sale of partridges until 1915; and increasing the fee for a resident big game license from $2 to $3.

Newfoundland.—One act: Lengthening the season two weeks on partridge, ptarmigan, willow grouse, plover, curlew, snipe, and other migratory birds.

Ontario.—One act: Repealing the authority of lieutenant governor in council to require nonresident licensees to employ guides while hunting big game and for making regulations for Rondeau Park, and permitting game animals bred in captivity to be possessed and sold at any time under permit.

Quebec.—One act: Shortening the season on moose and deer two months in Labelle and Temiscaming Counties; lengthening the season on hares six weeks; permitting the killing of any game animal injuring or threatening damage to property (but in the case of big game actual damage must have been caused); prohibiting the sale of all game during the first three days of the open season and of birch or swamp partridge until 1917.

Saskatchewan.—One act: Providing no open season for big game south of latitude 52° and shifting the season to open two weeks earlier; shortening the season two weeks on shore birds, rail, and waterfowl and six weeks on cranes; lengthening the season one month on grouse; establishing a bag limit of 50 a day and 250 a season on waterfowl; and prohibiting the killing of waterfowl from yacht or launch propelled by steam, gasoline, or electric motive power; increasing the export fee on big game from $1 to $5 a head; permitting the sale of all game except Gallinæ under a $5 dealer's license; increasing the fee for a resident big-game license from $2 to $5 and requiring holder of said license to wear a complete outer suit and cap of white and fixing a penalty of $500 to $1,000, or six months imprisonment for accidentally shooting a person and shall be ineligible to receive a license for 10 years; authorizing complimentary licenses to be granted to certain Canadian officials; and providing that the game laws shall apply to all Indians whether resident upon a reserve or elsewhere.

SEASONS.

The most important game legislation during the year was undoubtedly the act of Congress protecting migratory birds. In accordance with this act regulations were published by the Department of Agriculture (Cir. No. 92, Bureau of Biological Survey) on June 23, 1913, and if finally adopted will become effective on or after October 1, 1913, when approved by the President. As these regulations modify existing seasons of certain species to a considerable extent, they are published in full although subject to change before final approval.

PROPOSED REGULATIONS FOR THE PROTECTION OF MIGRATORY BIRDS.

Pursuant to the provisions of the act of March 4, 1913, authorizing and directing the Department of Agriculture to adopt suitable regulations prescribing and fixing closed seasons for migratory birds (37 Stat., 847), having due regard to zones of temperature, breeding habits, and times and lines of migratory flight, the Department of Agriculture has adopted the following regulations:

Regulation 1. Definitions.

For the purposes of these regulations the following shall be considered migratory game birds:

(*a*) Anatidæ or waterfowl, including brant, wild ducks, geese, and swans.

(*b*) Gruidæ or cranes, including little brown, sandhill, and whooping cranes.

(*c*) Rallidæ or rails, including coots, gallinules, and sora and other rails.

(*d*) Limicolæ or shore birds, including avocets, curlew, dowitchers, godwits, knots, oyster catchers, phalaropes, plover, sandpipers, snipe, stilts, surf birds, turnstones, willet, woodcock, and yellow legs.

(*e*) Columbidæ or pigeons, including doves and wild pigeons.

For the purposes of these regulations the following shall be considered migratory insectivorous birds:

(*f*) Bobolinks, catbirds, chickadees, cuckoos, flycatchers, grosbeaks, humming birds, kinglets, martins, meadow larks, night hawks or bull bats, nuthatches, orioles, robins, shrikes, swallows, swifts, tanagers, titmice, thrushes, vireos, warblers, waxwings, whippoorwills, woodpeckers, and wrens, and all other perching birds which feed entirely or chiefly on insects.

Regulation 2. Closed seasons at night.

A daily closed season on all migratory game and insectivorous birds shall extend from sunset to sunrise.

Regulation 3. Closed season on insectivorous birds.

A closed season on migratory insectivorous birds shall continue to December 31, 1913, and each year thereafter shall begin January 1 and continue to December 31, both dates inclusive, provided that nothing in this regulation shall be construed to prevent the issue of permits for collecting such birds for scientific purposes in accordance with the laws and regulations in force in the respective States and Territories and the District of Columbia; and provided further that the closed season on redbirds or ricebirds in Delaware, Maryland, the District of Columbia, Virginia, and South Carolina shall begin November 1 and end August 31 next following, both dates inclusive.

Regulation 4. Five-year Closed Seasons on Certain Game Birds.

A closed season shall continue until September 1, 1918, on the following migratory game birds: Band-tailed pigeons, little brown, sandhill, and whooping cranes, swans, curlew, and all shorebirds except the black-breasted and golden plover, Wilson or jacksnipe, woodcock, and the greater and lesser yellow legs.

A closed season shall also continue until September 1, 1918, on wood ducks in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Indiana, Michigan, West Virginia, and Wisconsin; on rails in California and Vermont; and on woodcock in Illinois and Missouri.

Regulation 5. Closed Season on Certain Navigable Rivers.

A closed season shall continue between January 1 and October 31, both dates inclusive, of each year, on all migratory birds passing over or at rest on any of the waters of the main streams of the following navigable rivers, to wit: The Mississippi River between New Orleans, La., and Minneapolis, Minn.; the Ohio River between its mouth and Pittsburgh, Pa.; and the Missouri River between its mouth and Bismarck, N. Dak.; and on the killing or capture of any of such birds on or over the shores of any of said rivers, or at any point within the limits aforesaid, from any boat, raft, or other device, floating or otherwise, in or on any such waters.

Regulation 6. Zones.

The following zones for the protection of migratory game and insectivorous birds are hereby established:

Zone No. 1, the breeding zone, comprising States lying wholly or in part north of latitude 40° and the Ohio River, and including Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, Nebraska, Colorado, Wyoming, Montana, Idaho, Oregon, and Washington—25 States.

Zone No. 2, the wintering zone, comprising States lying wholly or in part south of latitude 40° and the Ohio River and including Delaware, Maryland, the District of Columbia, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Kentucky, Missouri, Arkansas, Louisiana, Texas, Oklahoma, Kansas, New Mexico, Arizona, California, Nevada, and Utah—23 States and the District of Columbia.

Regulation 7. Construction.

For the purposes of regulations 8 and 9, each period of time therein prescribed as a closed season shall be construed to include the first day and to exclude the last day thereof.

Regulation 8. Closed Seasons in Zone No. 1.

Closed seasons in zone No. 1 shall be as follows:

Waterfowl.—The closed season on waterfowl shall be between December 16 and September 1 next following, except as follows:

Exceptions: In Massachusetts the closed season shall be between January 1 and September 15.

In Minnesota and North Dakota the closed season shall be between December 16 and September 7.

In South Dakota the closed season shall be between December 16 and September 10.

In New York, other than on Long Island, and in Oregon the closed season shall be between December 16 and September 16.

In New Hampshire, Long Island, New Jersey, and Washington the closed season shall be between January 16 and October 1.

Rails.—The closed season on rails, coots, and gallinules shall be between December 1 and September 1 next following, except as follows:

Exceptions: In Massachusetts and Rhode Island the closed season shall be between December 1 and August 1.

In New York and on Long Island the closed season shall be between December 1 and September 16; and

On rails in California and Vermont the closed season shall be until September 1, 1918.

Woodcock.—The closed season on woodcock shall be between December 1 and October 1 next following, except as follows:

Exceptions: In Maine and Vermont the closed season shall be between December 1 and September 15.

In Massachusetts, Connecticut, and New Jersey the closed season shall be between December 1 and October 10.

In Rhode Island, Pennsylvania, and on Long Island the closed season shall be between December 1 and October 15; and

In Illinois and Missouri the closed season shall be until September 1, 1918.

Shore birds.—The closed season on black-breasted and golden plover, jacksnipe or Wilson snipe, and greater or lesser yellowlegs shall be between December 16 and September 1 next following, except as follows:

Exceptions: In Maine, Massachusetts, and on Long Island the closed season shall be between December 16 and August 1.

In Minnesota and North Dakota the closed season shall be between December 16 and September 7.

In South Dakota the closed season shall be between December 16 and September 10.

In New York, other than Long Island, and in Oregon the closed season shall be between December 16 and September 16; and

In New Hampshire and Washington the closed season shall be between December 16 and October 1.

Regulation 9. Closed Seasons in Zone No. 2.

Closed seasons in zone No. 2 shall be as follows:

Waterfowl.—The closed season on waterfowl shall be between January 16 and October 1 next following, except as follows:

Exceptions: In Kansas, Oklahoma, New Mexico, and Arizona the closed season shall be between December 16 and September 1; and

In Maryland, Virginia, North Carolina, and South Carolina the closed season shall be between February 1 and November 1.

Rails.—The closed season on rails, coots, and gallinules shall be between December 1 and September 1 next following, except as follows:

Exceptions: In Tennessee and Louisiana the closed season shall be between December 1 and October 1; and

In Arizona the closed season shall be between December 1 and October 15.

Woodcock.—The closed season on woodcock shall be between January 1 and November 1, except as follows:

Exceptions: In Louisiana the closed season shall be between January 1 and November 15; and

In Georgia the closed season shall be between January 1 and December 1.

Shore birds.—The closed season on black-breasted and golden plover, jacksnipe or Wilson snipe, and greater and lesser yellowlegs shall be between December 16 and September 1, next following, except as follows:

Exceptions: In Alabama the closed season shall be between December 16 and November 1.

In Louisiana and Tennessee the closed season shall be between December 16 and October 1.

In Arizona the closed season shall be between December 16 and October 15.

In Utah, on snipe the closed season shall be between December 16 and October 1, and on plover and yellowlegs shall be until September 1, 1918.

Regulation 10. Hearings.

Persons recommending changes in the regulations or desiring to submit evidence in person or by attorney as to the necessity for such changes should make application to the Secretary of Agriculture. Whenever possible hearings will be arranged at central points, and due notice thereof given by publication or otherwise as may be deemed appropriate. Persons recommending changes should be prepared to show the necessity for such action and to submit evidence other than that based on reasons of personal convenience or a desire to kill game during a longer open season.

OPEN SEASONS.

All the general open seasons for game prescribed by the various States and by the Provinces of Canada are here brought together in one table. For the sake of simplicity a uniform method is used in both the arrangement of species and statement of seasons. In each case deer and other big game are first considered; then rabbits and squirrels; then upland game birds, such as quail, grouse, pheasants, turkeys, and doves; then shore birds; and finally waterfowl, such as ducks, geese, and swans. In stating the seasons the plan of the Vermont law, to include the first date but not the last, has been followed consistently.[1] The Vermont scheme has the advantage of showing readily both the open and close seasons, since either may be obtained by reversing the dates of the other.

In some States certain days of the week constitute close seasons throughout the time in which killing is permitted. Hunting on Sunday is prohibited in all of the States and Provinces east of the one hundred and fifth meridian except Illinois, Louisiana, Michigan, Texas, Wisconsin, and Quebec. Mondays constitute a close season for waterfowl in Ohio, and locally in Maryland and North Carolina; and other week days for wild fowl in several favorite ducking grounds in Delaware, Maryland, Virginia, and North Carolina. Hunting is prohibited on election day in Allegany, Baltimore, Cecil, Frederick, and Harford Counties, Md.; and when snow is on the ground in New Jersey, Delaware, Virginia, and Maryland. The county laws of Maryland and North Carolina, which are too numerous to be included satisfactorily, are not incorporated in the following table,[2] which otherwise may be regarded as a practically complete résumé of the regulations now in force. The difficulty of securing absolute accuracy in a table of this kind is very great, and the absence in the laws of many States of express legislation as to the inclusion or exclusion of the date upon which seasons open and close makes exactness almost an impossibility.

In the following table all dates in black-faced type are in accordance with the proposed regulations for the protection of migratory birds, which do not take effect until October 1 or on approval by the President. As these regulations have not yet been approved, the opening date of the season for 1913 under State laws has been indicated. *Names of birds in black-faced type* indicate in most cases that these species are protected only by the Federal law. Species like the curlew, upland plover, swan, the smaller shore birds, and the wood duck in Zone No. 1, which will be protected for five years under the proposed regulations are not included in the table unless mentioned in the State law.

All seasons for migratory birds are necessarily provisional and subject to change when the regulations take effect.

[1] See discussion of this question in Circular No. 43 of the Biological Survey, U. S. Department of Agriculture, 1904, entitled "Definitions of the open and close seasons for game."

[2] The county laws of Maryland are shown in Poster No. 28, and those of North Carolina in Poster No. 30, copies of which may be had free on application to the Biological Survey, U. S. Department of Agriculture.

PROVISIONAL OPEN SEASONS FOR GAME IN THE UNITED STATES AND CANADA, 1913.

[The open seasons include the first date, but not the last. To find the close seasons, *reverse the dates.* Seasons which apply only to special counties are placed to the left of the column containing those for the State in general. Future dates, as Aug. 1, 1914, indicate that the season does not open until that time.]

	Open seasons.
Alabama (1907–1911):	
Male deer (does protected all the year)	Nov. 1–Jan. 1.
Squirrel (black, gray, or fox)	Oct. 1–Mar. 1.
Quail or partridge	Nov. 1–Mar. 1.
Wild turkey gobblers (hens protected all the year)	Dec. 1–Apr. 1.
Ruffed grouse (pheasant), imported pheasant, or other introduced game birds	Dec. 1–Dec. 15.
Dove	Aug. 1–Mar. 1.
Plover, snipe	Nov. 1–**Dec. 16.**
Yellowlegs	Sept. 1–**Dec. 16.**
Curlew, sandpiper, other shore birds, swan	Sept. 1–Mar. 15.
Woodcock	Sept. 1–**Jan. 1.**
Rail, coot, mud hens	Sept. 1–**Dec. 1.**
Duck, goose, brant	Sept. 1–**Jan. 16.**
Alaska [1] (1910–1913):	
North of latitude 62°—	
Moose (females and yearlings protected all the year), caribou, sheep	Aug. 1–Dec. 11.
South of latitude 62°—	
Deer (see exception)	Aug. 15–Nov. 2.
Exception: Deer on Duke, Gravina, Kruzof, Suemez, and Zarembo Islands, Aug. 1, 1914; Kodiak and Long Islands, Dec. 10, 1914.	
Mountain goat	Aug. 1–Feb. 2.
Moose (females and yearlings protected all the year), caribou (see exception), sheep	Aug. 20–Jan. 1.
Exception: Caribou on the Kenai Peninsula, Aug. 1, 1914.	
Brown bear	Oct. 1–July 2.
Throughout Territory—	
Grouse, ptarmigan, shore birds, waterfowl	Sept. 1–Mar. 2.
Arizona (1912):	
Male deer	Oct. 1–Dec. 16.
Female deer, spotted fawn, elk, antelope, sheep, goat	No open season.
Bobwhite, grouse, pheasant	No open season.
Quail	Oct. 15–Feb. 2.
Wild turkey	Oct. 1–Dec. 16.
Dove and white wing	June 1–Feb. 2.
Duck, goose, and brant	Sept. 1–**Dec. 16.**
Snipe, **plover, yellowlegs**	Oct. 15–**Dec. 16.**
Rail, **coot, gallinule**	Oct. 15–**Dec. 1.**
Arkansas (1901–1913):	
Deer (see exceptions)	Sept. 1–Feb. 1.
Exceptions:	
Chicot County	Oct. 1–Feb. 1.
Desha County	Oct. 1–Jan. 1.
Squirrel in Lee, Monroe, Phillips, and St. Francis Counties	May 1–Dec. 1.
Quail or partridge (see exceptions)	Nov. 1–Mar. 1.
Exceptions:	
Bradley and Dallas Counties	Nov. 15–Mar. 1.
Carroll, Columbia, Grant, and Lafayette Counties	Dec. 10–Feb. 1.
Boone County, quail	Mar. 29, 1917.
Calhoun county, nonresident not permitted to hunt quail or partridge.	
Prairie chicken, pinnated grouse (see exception)	Nov. 1–Dec. 1.
Exception: Prairie County	Jan. 1, 1917.
Wild turkey (see exception)	Sept. 1–May 1.
Exception: Chicot County	Feb. 1–May 15.
Pheasants (Chinese, English) 10 years	Mar. 14, 1913.
Dove	No open season.
Black-breasted and golden plover, jacksnipe, Wilson snipe, and yellowlegs [2]	**Sept. 1–Dec. 16.**
Woodcock	**Nov. 1–Jan. 1.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, goose, brant	**Oct. 1–Jan. 16.**

[1] Game animals or birds may be killed at any time for food or clothing by native Indians or Eskimo, or by miners or explorers in need of food, but game so killed can not be shipped or sold.

[2] See Regulation 4.

	Open seasons.
California (1901–1913):[1]	
Male deer in second, fourth, and fifth districts	July 1–Sept. 1.
In first, third, and seventh districts	Aug. 15–Nov. 1.
In sixth district	Aug. 15–Sept. 15.
Female deer, fawn, elk, antelope, sheep	No open season.
Cottontail rabbit, bush rabbit	July 31–Feb. 1.
Tree squirrel (except in Mendocino County, unprotected)	Sept. 1–Jan. 1.
Valley quail (except sixth district, Oct. 15–Nov. 15)	Oct. 15–Feb. 15.
Mountain quail, grouse, sage hen	Sept. 1–Dec. 1.
Pheasant, bobwhite quail, imported quail or partridge, wild turkey, swan	No open season.
Dove	July 15–Oct. 1.
In second and fifth districts	Aug. 1–Oct. 15.
In fourth and sixth districts and Inyo County of the seventh district	Sept. 1–Nov. 1.
Black-breasted and golden plover, Wilson or jacksnipe	Nov. 15–**Dec. 16.**
Rail, band tailed pigeon (Regulations Nos. 4 and 8)	**Sept. 1, 1918.**
Duck	Oct. 15–**Jan. 16.**
Black brant (opens Oct. 1 in first district)	Nov. 1–**Jan. 16.**
Colorado (1899–1913):	
Deer with horns	Oct. 1, 1918.
Elk, 15 years	Nov. 1, 1924.
Antelope, 13 years; sheep with horns, 15 years	Sept. 25, 1924.
Deer, antelope, sheep, without horns	No open season.
Partridge, ptarmigan, wild turkey, wild pigeon	No open season.
Quail (bobwhite, crested), 13 years	Oct. 1, 1924.
Pheasant, black game, capercailzie	Sept. 1, 1924.
Prairie chicken, mountain and willow grouse	Aug. 15–Oct. 11.
Sage chicken	Sept. 1–Apr. 21.
Dove	Aug. 15–Sept. 1.
Plover, snipe	Sept. 1–**Dec. 16.**
Yellowlegs	Aug. 1–**Dec. 16.**
Curlew (under Regulation No. 4)	**Sept. 1, 1918.**
Rails, coots, gallinules	**Sept. 1–Dec. 1.**
Duck, goose, brant	Sept. 1–**Dec. 16.**
Connecticut (1901–1913):	
Deer, 6 years	**June 1, 1917.**
Hare, rabbit	Oct. 8–Jan. 1.[2]
Gray squirrel	Oct. 8–Nov. 24.
Quail, ruffed grouse, pheasant (Chinese, English, Mongolian), woodcock	Oct. 8–Nov. 24.
Hungarian partridge	Nov. 1–24, 1913.
Dove	No open season.
Black-breasted and golden plover, Wilson or English snipe, yellowlegs, duck (except wood duck, Sept. 1, 1919), goose, brant	Sept. 1–**Dec. 16.**
Rail	Sept. 12–**Dec. 1.**
Mud-hen, gallinule	Sept. 1–**Dec. 1.**
Delaware (1893–1913):	
Rabbit, hare, squirrel (fox, black, gray)	Nov. 15–Jan. 1.
Quail, partridge, woodcock	Nov. 15–Jan. 1.
Hungarian partridge, pheasant, swan	No open season.
Dove (except in Newcastle County, no open season)	Aug. 1–Jan. 1.
Reedbird, ortolan, or rail	Sept. 1–Nov. 1.
Duck (except wood duck, Sept. 1–Nov. 1), goose, brant	**Oct. 1–Jan. 16.**
Black-breasted and golden plover, jacksnipe or Wilson snipe, yellowlegs	**Sept. 1–Dec. 16.**

[1] Seasons fixed by ordinances of boards of county supervisors are omitted. The following seven fish and game districts have been established in California: *First district:* Northern counties, including Siskiyou, Modoc, Lassen, Shasta, Trinity, Tehama. *Second district:* Coast counties north of Suisun Bay and west of the Sacramento River, including Del Norte, Humboldt, Mendocino, Glenn, Colusa, Lake, Sonoma, Napa, Yolo, Solano, Marin. *Third district:* Counties of the eastern Sacramento Valley and central Sierra, including Plumas, Butte, Sierra, Yuba, Sutter, Nevada, Placer, El Dorado, Sacramento, Amador, Calaveras, San Joaquin, Tuolumne, Mariposa. *Fourth district:* San Joaquin Valley counties, including Madera, Tulare, and east of the San Joaquin River in Stanislaus, Merced, Fresno, Kings, Kern. *Fifth district:* Counties west of the Coast Range from Suisun Bay to Santa Barbara, including Contra Costa, Alameda, San Francisco, San Mateo, Santa Clara, Santa Cruz, San Benito, Monterey, San Luis Obispo, Santa Barbara, and west of San Joaquin River in Stanislaus, Merced, Fresno, Kings, and Kern counties. *Sixth district:* Southern California, including counties of Ventura, Los Angeles, Orange, San Diego, Imperial, Riverside, and San Bernardino. *Seventh district:* Central counties east of the Sierra, including Alpine, Mono, and Inyo.

[2] Between Nov. 24 and Jan. 1 hunting is permitted with dog and ferret only.

	Open seasons.
District of Columbia [1] (1899–1906):	
Deer meat (sale or possession)	Sept. 1–Jan. 1.
Rabbit (except English rabbit, Belgian hare), squirrel	Nov. 1–Feb. 1.
Quail or partridge	Nov. 1–Mar. 15.
Ruffed grouse or pheasant (except English, ringneck, or other imported pheasants raised in inclosures, sale or possession unrestricted), wild turkey	Nov. 1–Dec. 26.
Prairie chicken (pinnated grouse)	Sept. 1–Mar. 15.
Dove	No open season.
Woodcock	July 1–Jan. 1.
Plover, snipe, marsh blackbird, duck, goose, brant	Sept. 1–**Dec. 16.**
Reedbird	Sept. 1–**Nov. 1.**
Rail or ortolan	**Sept. 1.**–Dec. 1.
Florida (1913):	
Deer, males only (does and fawns, no open season), squirrel	Nov. 20–Feb. 21.
Quail (bobwhite partridge), wild turkey gobblers (hens, no open season), dove	Nov. 20–Feb. 21.
Ruffed grouse, imported pheasants	Dec. 1, 1915.
Plover, snipe, **yellowlegs**	Nov. 20–**Dec. 16.**
Rail, coot, **gallinule**	Nov. 20–**Dec. 1.**
Duck, goose, brant	Nov. 20–**Jan. 16.**
Georgia (1905–1912):	
Deer (except does and fawns, Dec. 1, 1916)	Oct. 1–Dec. 1.
Cat squirrel (fox squirrel, Jan. 1, 1918)	Aug. 1–Jan. 1.
Quail, partridge, wild turkey (gobblers), dove	Nov. 20–Mar. 1.
Pheasant or ruffed grouse, wild turkey hens, imported game birds	Dec. 1, 1916.
Plover	Nov. 20–**Dec. 16.**
Snipe	Dec. 1–**Dec. 16.**
Yellowlegs	**Sept. 1–Dec. 16.**
Woodcock	Dec. 1–Jan. 1.
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Ducks (except wood duck, Dec. 1–Jan. 1)	Sept. 1–**Jan. 16.**
Geese, brant	**Oct. 1–Jan. 16.**
Idaho (1909–1911):	
Deer, elk, sheep, goat (see exceptions)	Sept. 1–Dec. 1.
Exceptions.—In Bonner, Clearwater, Idaho, Kootenai, Latah, Nez Perce, and Shoshone Counties, deer, Sept. 20–Dec. 20; elk, Sept. 1, 1916; in Fremont, Bonneville, and Bingham Counties, elk, Sept. 1–Jan. 1; in Bear Lake, Cassia, Oneida, and Twinfalls Counties, deer, elk, sheep, and goat, Sept. 1, 1916.	
Moose, caribou, antelope, buffalo	No open season.
Quail	Nov. 1–Dec. 1.
Partridge, pheasant, grouse (except north of Salmon River, Sept. 1–Dec. 1)	Aug. 15–Dec. 1.
Turtle dove (except in Fremont County, Aug. 15–Dec. 1), sage hen	July 15–Dec. 1.
Prairie chicken, pinnated grouse, imported pheasant	No open season.
Swan	Sept. 1, **1918.**
Plover, snipe, **yellowlegs**	Sept. 1–**Dec. 16.**
Duck, goose, **brant**	Sept. 1–**Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Illinois (1903–1913):	
Deer,[2] 10 years	June 23, 1923.
Squirrel (gray, red, fox, or black)	July 2–Nov. 15.
Quail	Nov. 11–Dec. 10.
Prairie chicken	Nov. 11–Nov. 25.
Ruffed grouse, partridge, blue quail, mountain quail, valley quail, Hungarian partridge, capercailzie, heath hen, black grouse, woodcock	July 2, 1920.
Wild turkey, pheasants [2] (copper or Soemmering, English, golden, green Japanese, Mongolian, ringneck, silver, tragopan, Reeves, Elliot, Hungarian, Swinhoe, Amherst, melanotte, impeyan, argus), partridge (black Indian, caccabis, chukar), sand grouse, 10 years	June 23, 1923.
Mourning dove	Aug. 16–Nov. 1.
Plover, snipe, **yellowlegs,** duck, goose, brant	Sept. 2–**Dec. 16.**
Coot, rail, gallinule	Sept. 2–**Dec. 1.**

[1] Hunting prohibited in the District, by act of June 30, 1906, except on the marshes of the Eastern Branch above the Anacostia Bridge, and on the Virginia shore of the Potomac, and no birds can be shot within 200 yards of any bridge or dwelling.

[2] Deer raised in inclosure for market may be killed Oct. 1–Feb. 1; cock pheasant, Nov. 1–Feb. 1 under permit.

	Open seasons.
Indiana (1905–1913):	
Deer[1]	No open season.
Rabbit	Apr. 1–Jan. 10.
Squirrel	July 1–Oct. 1.
Quail, ruffed grouse	Nov. 10–Dec. 21.
Prairie chicken, Hungarian partridge, pheasants (copper, golden, green, Hungarian, ringneck, silver, tragopan)	Mar. 6, 1915.
Wild turkey, dove	No open season.
Woodcock	July 1–**Dec. 1.**
Black-breasted and golden plover, jacksnipe or Wilson snipe, and yellowlegs	**Sept. 1–Dec. 16.**
Rail, coot, and gallinule	**Sept. 1–Dec. 1.**
Duck, goose, brant	Sept. 1–**Dec. 16.**
Iowa (1897–1907):	
Deer, elk	No open season.
Squirrel (gray, timber, or fox)	Sept. 1–Jan. 1.
Quail, ruffed grouse or pheasant, wild turkey	Nov. 1–Dec. 15.
Prairie chicken (pinnated grouse)	Sept. 1–Dec. 1.
Pheasants (English, Mongolian, Chinese, ringneck)	Oct. 1, 1915.
Turtle dove	No open season.
Woodcock	July 10–**Dec. 1.**
Black-breasted and golden plover, Wilson or jacksnipe, yellowlegs, duck, goose, brant	Sept. 1–**Dec. 16.**
Rail, **coot, gallinule**	Sept. 1–**Dec. 1.**
Kansas (1903–1913):	
Deer, antelope, 10 years	Mar. 24, 1921.
Fox squirrel (red, gray, and black, no open season)	Sept. 1–Jan. 1.
Quail, prairie chicken, pheasants (English, Mongolian, or Chinese), Hungarian partridge, 5 years	Mar. 19, 1918.
Grouse	Oct. 1–Nov. 2.
Plover	Aug. 1–**Dec. 16.**
Snipe, duck, goose, brant	Sept. 1–**Dec. 16.**
Yellowlegs	**Sept. 1–Dec. 16.**
Woodcock	**Nov. 1–Jan. 1.**
Rails, coots, gallinules	**Sept. 1–Dec. 1.**
Kentucky (1894–1906):	
Deer	Sept. 1–Mar. 1.
Rabbit (except with dogs or snares)	Nov. 15–Sept. 15.
Squirrel (black, gray, or fox)	June 15–Sept. 15. Nov. 15–Feb. 1.
Quail, partridge, pheasant	Nov. 15–Jan. 1.
Pheasants (English, ringneck, Mongolian, or Chinese)	No open season.
Wild turkey	Sept. 1–Feb. 1.
Dove	Aug. 1–Feb. 1.
Woodcock	June 20–**Jan. 1.**
Black-breasted and golden plover, Wilson or jacksnipe, yellowlegs	**Sept. 1–Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, goose	Aug. 15–**Jan. 16.**
Brant	**Oct. 1–Jan. 16.**
Louisiana (1912):	
Deer (fawns no open season) 5 months,[2] including	Nov. and Dec.
Squirrels	July 2–Mar. 1.
Quail	Nov. 15–Mar. 1.
Prairie chicken, pheasant (imported or native), wild turkey hen, killdeer	Dec. 1, 1915.
Wild turkey (male)	Nov. 15–Apr. 1.
Dove	Sept. 1–Mar. 1.
Woodcock	Nov. 15–**Jan. 1.**
Papabotte, upland plover (under Regulation No. 4)	**Sept. 1, 1918.**
Plover (except killdeer and upland plover)	Oct. 1–**Dec. 16.**
Snipe	Sept. 15–**Dec. 16.**
Rail, coot, gallinule	Oct. 1–**Dec. 1.**
Duck (except wood duck, black mallard, and blue-winged teal), goose, brant	Oct. 1–**Jan. 16.**
Blue-winged teal	Sept. 15–**Jan. 16.**
Florida duck (black mallard)	Aug. 1–**Jan. 16.**
Wood duck	Sept. 1–**Jan. 16.**

[1] Deer raised in private preserves may be killed at any time.

[2] Season fixed by conservation commission.

	Open seasons.
Maine (1903–1913):	
Deer in Aroostook, Franklin, Hancock, Oxford, Penobscot, Piscataquis, Somerset, and Washington Counties (see exceptions)	Oct. 1–Dec. 16.
Exceptions:	
Mount Desert Island, no open season.	
Swan Island, 4 years	Oct. 1, 1914.
Washington County—Cross and Scotch Islands	July 3, 1919.
Deer in rest of State	Nov. 1–Dec. 1.
Bull moose with at least two 3-inch prongs on horns	Nov. 1–Dec. 1.
Cow and calf moose	No open season.
Caribou, 6 years	Oct. 15, 1917.
Hare, rabbit	Sept. 1–Apr. 1.
Squirrel, gray	Sept. 1–Nov. 1.
Quail, Hungarian partridge, pheasant, black game, capercailzie, cock of the woods, dove	No open season.
Ruffed grouse, partridge, woodcock	Sept. 15–Dec. 1.
Plover, snipe, yellowlegs	Aug. 1–Dec. 1.
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, **goose, brant**	**Sept. 1–Dec. 16.**
Maryland (1898–1912):[1]	
Rabbit	Nov. 1–Dec. 25.
Squirrel	Sept. 1–Dec. 2.
Quail, ruffed grouse, wild turkey	Nov. 1–Dec. 25.
Dove	Aug. 15–Dec. 25.
Plover, snipe	Aug. 15–**Dec. 16.**
Woodcock	**Nov. 1**–Dec. 25.
Reedbird, sora (water rail or ortolan)	**Sept. 1–Nov. 1.**
Duck, goose, brant	Nov. 1–**Feb. 1.**
Coot and gallinule	**Sept. 1–Dec. 16.**
Yellowlegs	**Sept. 1–Dec. 16.**
Massachusetts (1902–1913):	
Deer (third Monday in November to the following Saturday, inclusive)	Nov. 17–22, 1913.
Moose	No open season.
Hare or rabbit	Oct. 16–Mar. 1.
Gray squirrel	Oct. 12–Nov. 13.
Quail, ruffed grouse or partridge, woodcock	Oct. 12–Nov. 13.
Dove, wild or passenger pigeon, prairie chicken, Hungarian partridge, pheasants (English, golden, Mongolian),[2] killdeer or piping plover, swan	No open season.
Heath hen, 5 years	Nov. 1, 1916.
Wild turkey, 4 years	Sept. 1, 1915.
Bartramian sandpiper (upland plover)	July 15, 1915.
Plover (except upland and killdeer or piping plover), snipe	**Aug. 1–Dec. 16.**
Rail, gallinule, quark (mud hen)	**Aug. 1–Dec. 1.**
Duck (except wood duck), teal, brant	Sept. 15–Jan. 1.
Michigan (1905–1913):	
Deer[3] (see exceptions)	Nov. 10–Dec. 1.
Exceptions: Deer in red coat and fawn in spotted coat, and all deer in Berrien, Calhoun, Genesee, Ingham, Jackson, Kalamazoo, Oakland, and St. Clair Counties	Nov. 10, 1920.
Bois Blanc Island	Nov. 10, 1918.
Elk, moose, caribou	No open season.
Rabbit	Sept. 1–Mar. 2.
Squirrel (black, fox, or gray), 3 years	Oct. 15, 1915.
Quail, pheasants (English, Mongolian), black game, capercailzie, hazel grouse, wild turkey	Nov. 1, 1917.
Ruffed grouse (partridge), spruce hen, woodcock	Oct. 1–Dec. 1.
Pinnated grouse (prairie chicken), European partridge, dove, swan	No open season.
Plover, snipe, **yellowlegs,** duck, goose, brant	Sept. 1–**Dec. 16.**
Rail, coot, **gallinule**	Sept. 15–**Dec. 1.**

[1] The seasons given are the most general. For all seasons under county laws see Poster No. 28, "Open seasons for game, District of Columbia, Maryland, and Virginia, 1913," which may be had upon application to the Biological Survey, U. S. Department of Agriculture, Washington, D. C.

[2] Except on private preserves under permit of commissioners on fisheries and game.

[3] Deer raised in captivity may be killed at any time for owner's consumption.

	Open seasons.
Minnesota (1905–1909):	
Deer, male moose	Nov. 10–Nov. 30.
Elk, female moose, caribou, fawn	No open season.
Quail, partridge, ruffed grouse (pheasant)	Oct. 1–Dec. 1.
Sharp-tailed or white-breasted grouse, prairie chicken (pinnated grouse), turtle dove, golden plover, Wilson or jack snipe, woodcock	Sept. 7–Nov. 7.
Pheasants (Chinese, English, Mongolian)	No open season.
Duck, goose, brant	Sept. 7–Dec. 1.
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Mississippi [1] (1906–1910):	
Deer (female deer and spotted fawn, no open season), bear	Nov. 15–Mar. 1.
Quail or partridge	Nov. 1–Mar. 1.
Wild turkey (hens, no open season)	Jan. 1–May 1.
Dove	July 1–Mar. 1.
Plover, tatler, chorook, grosbec, **Jacksnipe or Wilson snipe, and yellowlegs**	Sept. 1–**Dec. 16.**
Coot (poule d'eau), rail (mud hen), **gallinule**	Sept. 1–**Dec. 1.**
Duck, goose, brant	Sept. 1–**Jan. 16.**
Cedar bird	Sept. 1–Mar. 1.
Missouri (1909–1913):	
Deer, males only (no open season for does or fawns under 1 year of age)	Nov. 1–Jan. 1.
Squirrel (gray, black, fox)	July 1–Dec. 1.
Quail (bobwhite, partridge)	Dec. 1–Jan. 1.
Wild turkey	Nov. 1—Jan. 1.
Dove	Sept. 1–Jan. 1.
Ruffed grouse (pheasant), prairie chicken (pinnated grouse), Mongolian, Chinese, and English pheasants, woodcock, and other game birds	No open season.
Plover, **yellowlegs**	Sept. 1–**Dec. 16.**
Snipe	Sept. 15–**Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, goose, brant	Sept. 15–**Jan. 16.**
Montana (1905–1913):	
Deer, sheep, goat	Oct. 1–Dec. 1.
Elk (see exceptions)	Oct. 1, 1918.
Exceptions: In counties of Sweetgrass, Park, Gallatin, Madison, Teton, Flathead, and those portions of Powell and Missoula Counties drained by South Fork of Flathead and Swan Rivers, respectively, Beaverhead County east of Oregon Short Line Railroad between Willis and Armstead, and Beaverhead County south of Pittsburg and Gilmore Railroad	Oct. 1–Dec. 1.
Moose, caribou, fawns, female sheep, and lambs, antelope, bison or buffalo	No open season.
Quail, Chinese pheasant, Hungarian pheasant, dove	No open season.
Pheasant, partridge, prairie chicken, sage hen, fool hen, grouse	Oct. 1–Nov. 1.
Duck, goose, brant	Sept. 1–**Dec. 16.**
Black-breasted and golden plover, jacksnipe or Wilson snipe, and yellowlegs	**Sept. 1–Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Nebraska (1901–1911):	
Deer, elk, antelope	No open season.
Squirrel (gray, red, fox, timber)	Oct. 1–Dec. 1.
Quail	Nov. 1–Nov. 16.
Dove, plover (except killdeer)	July 15–Sept. 1.
Prairie chicken, sage chicken, grouse	Sept. 1–Dec. 1.
Partridge, pheasant, ptarmigan, English partridge, Belgian partridge, English pheasant, Chinese pheasant, Mongolian pheasant, English black cock, other imported game birds, wild pigeon, wild turkey, curlew, white crane, swan	No open season.
Yellowlegs, jacksnipe, Wilson snipe, duck, goose, brant	Sept. 1–**Dec. 16.**
Rail, coot, and gallinule	**Sept. 1–Dec. 1.**
Nevada [2] (1909–1913):	
Deer (males only)	Oct. 15–Nov. 16.
Antelope, female deer, spotted fawn	No open season.
Mountain sheep and goat	Jan. 1, 1920.
Mountain quail	Oct. 1–Jan. 2.
Valley quail	Oct. 15–Jan. 16.
Grouse	Oct. 1–Dec 16.

[1] Local regulations of boards of supervisors also in force.

[2] County commissioners may change dates of close seasons (without altering length) and may open seasons for shorebirds and waterfowl Sept. 1.

	Open seasons.
Nevada—Continued.	
Bobwhite, partridge, pheasant, other imported birds	No open season.
Sage hen	July 15–Oct. 2.
Woodcock	Sept. 15–**Jan. 1.**
Plover, snipe	Sept. 15–**Dec. 16.**
Duck, goose, swan	Sept. 15–**Jan. 16.**
Brant	**Oct. 1–Jan. 16.**
Yellowlegs	**Sept. 1–Dec. 16.**
New Hampshire [1] (1901–1913):	
Deer in Coos County	Oct. 1–Dec. 16
Deer in Carroll and Grafton Counties	Nov. 1–Dec. 16
Deer in rest of State	Dec. 1–Dec. 16.
Elk, moose, caribou	No open season.
Hare, rabbit	Oct. 1–Apr. 1.
Gray squirrel	Oct. 1, 1919.
Exception: Outside of the thickly settled part of cities and towns	Oct. 1–Nov. 1
Quail, partridge, ruffed grouse, woodcock (see exception), Wilson snipe	Oct. 1–Dec. 1.
Exception: Woodcock in Coos and Grafton Counties	Sept. 15–Dec. 1
Dove, pheasant, any introduced foreign game bird	No open season.
Killdeer, upland plover or Bartramian sandpiper, wood duck	Oct. 1, 1917.
Black-breasted and golden plover, yellowlegs	Oct. 1–**Dec. 16.**[2]
Rail, coot, gallinule	**Sept. 1–Dec. 1.**[2]
Duck (except wood duck and sheldrake), **goose, brant**	Oct. 1–**Jan. 16.**[3]
New Jersey (1903–1913):	
Deer, bucks only [4] (no open season for does)	Nov. 1–Nov. 6.
Rabbit, squirrel	Nov. 10–Dec. 16.
Quail, ruffed grouse (partridge), prairie chicken, Hungarian partridge, English or ring-neck pheasant (females until 1914), wild turkey	Nov. 10–Dec. 16.
Dove, wild pigeon	No open season.
Woodcock	Oct. 10–Dec. 1.
Upland plover, 5 years	Aug. 1, 1916.
Plover (except upland plover), yellowlegs	May 1–**Dec. 16.**
English (Wilson) snipe (bog or jacksnipe)	Sept. 1–**Dec. 16.**
Curlew, surf (bay) snipe (except English snipe), sandpiper, and other shore birds	May 1–Jan. 1.
Reedbird	Sept. 1–**Nov. 1.**
Marsh hen, rail, **coot, gallinule**	Sept. 1–**Dec. 1.**
Duck (except wood duck, swan, **Sept. 1, 1918**), goose, brant	Nov. 1–**Jan. 16.**[5]
New Mexico (1912):	
Deer (with horns)	Oct. 1–Nov. 16.
Deer (without horns), elk, sheep, goat	No open season.
Antelope, 5 years	June 14, 1917.
Quail (except bobwhite)	Nov. 1–Feb. 1.
Bobwhite quail, pheasant, prairie chicken, wild pigeon, 5 years	June 14, 1917.
Grouse	Sept. 1–Nov. 16.
Ptarmigan (white grouse), Oregon or Denny pheasant	No open season.
Wild turkey	Nov. 1–Jan. 16.
Turtle dove	July 1–Oct. 1.
Plover, snipe, **yellowlegs**, duck, **goose, brant**	Sept. 1–**Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
New York [6] (1912–13):	
Deer, with horns not less than 3 inches long, in Adirondack region[7]	Oct. 1–Nov. 16.
Deer—rest of State (see exception)	No open season.
Exception: Deer having horns not less than 3 inches in length in Ulster County and towns of Neversink, Cochecton, Tusten, Highland, Lumberland, Forestburg, Bethel, and all of towns of Mamakating and Thompson south of Newburgh and Cochecton turnpike in Sullivan County and Deer Park in Orange County	Nov. 1–Nov. 16

[1] Governor and council may suspend open season in time of excessive drought.

[2] In Rockingham County the season on beach birds, coot, teal, opens July 15.

[3] On tide waters and salt marshes the season on black ducks opens September 1.

[4] Not applicable to deer in game preserves or to possession of imported deer properly tagged.

[5] Open season for duck, goose, and brant on Delaware River and Bay, begins Sept. 1.

[6] When first date of open season falls on Sunday, season opens on the preceding Saturday.

[7] The Adirondack region comprises the counties of Clinton, Essex, Franklin, Fulton, Hamilton, Herkimer, Oswego, Saratoga, St. Lawrence, Warren, and Washington, and that part of Jefferson, Lewis, and Oneida Counties lying east of the Utica & Black River R. R. from Utica to Ogdensburg.

New York—Continued.	*Open seasons.*
Elk, moose, caribou, antelope, female deer, and fawns	No open season.
Varying hare, rabbit	Oct. 1–Feb. 1.
Squirrel, black, gray, or fox	Oct. 1–Nov. 16.
Quail	Oct. 1, 1918.
Woodcock	Oct. 1–Nov. 16.
Grouse, partridge	Oct. 1–Dec. 1.
Hungarian or European gray-legged partridge, dove, wood duck, swan	No open season.
Wild pheasants, males only	Oct. 2, 9, 16, 23, 30[1]
Plover, snipe	Sept. 16–Dec. 1.
Rail, coot, mud hen, gallinule	**Sept. 16–Dec. 1.**
Waterfowl (except wood duck and swan)	**Sept. 16–Dec. 16.**
Long Island (1912–1913):	
Deer	No open season.
Varying hare, rabbit (cottontail)	Nov. 1–Jan. 1.
Squirrel, black, gray, fox	Nov. 1–Jan. 1.
Quail, pheasants (males only), grouse	Nov. 1–Jan. 1.
Dove	No open season.
Woodcock	Oct. 15–Dec. 1.
Plover, snipe	Aug. 1–Dec. 1.
Rail, coot, mud hen, gallinule	**Sept. 16–Dec. 1.**
Waterfowl (except wood duck and swan no open season)	Oct. 1–Jan. 11.
North Carolina[2] (1905–1911):	
Deer	Oct. 1–Feb. 1.
Quail, wild turkey, dove	Nov. 1–Mar. 1.
Black-breasted and golden plover, jacksnipe or Wilson snipe, yellowlegs	**Sept. 1–Dec.**
Woodcock	**Nov. 1–Jan. 1.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, goose, brant	**Nov. 1–Feb. 1.**
North Dakota (1909–1913):	
Deer, 3 years	Nov. 10, 1916.
Antelope, 11 years	Jan. 1, 1920.
Quail, partridge, English pheasant, Chinese ringneck pheasant, Hungarian partridge, dove, swan	No open season.
Prairie chicken (pinnated grouse), sharp-tailed (white-breasted) grouse, woodcock, golden plover, snipe	Sept. 7–Nov. 2.
Duck, goose, brant	Sept. 7–Dec. 16.
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Ohio (1900–1913):	
Rabbit	Nov. 15–Dec. 5.
Squirrel	Sept. 15–Oct. 21.
Raccoon	Nov. 1–Mar. 2.
Quail, ruffed grouse, introduced pheasant, dove	Nov. 15, 1915.
Woodcock, coot or mud hen, rail, gallinule	**Sept. 1–Dec. 1.**
Plover, snipe, shore birds, duck, goose, swan	**Sept. 1–Dec. 2.**[3]
Oklahoma (1909–1913):	
Deer (except females throughout State and males in Caddo, Comanche, Kiowa, and Swanson Counties, no open season)	Nov. 15–Dec. 15
Antelope, 5 years	Nov. 15, 1916.
Quail, Mexican (blue) quail	Nov. 15–Feb. 1.
Wild pigeon	No open season.
Prairie chicken	Sept. 1–Nov. 1.
Mongolian, Chinese, English, ringneck, or other pheasant	Nov. 1, 1914.
Wild turkey (additional season for gobblers, Mar. 15–Apr. 15)	Nov. 15–Jan. 1.
Dove	Aug. 15–May 1.
Black-breasted and golden plover, Wilson snipe, or jacksnipe, yellowlegs	**Aug. 15–Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, goose, brant	**Aug. 15–Dec. 16.**

[1] Pheasants are protected by order of the commission until October 1, 1914, in the 17 counties of Chenango, Clinton, Delaware, Essex, Franklin, Fulton, Herkimer, Jefferson, Lewis, Madison, Montgomery, Oneida, Otsego, Saint Lawrence, Schenectady, Warren, and Washington; and until October 1, 1915, in the three counties of Allegany, Cattaraugus, and Chautauqua.

[2] For county seasons see special poster of the Biological Survey, U. S. Department of Agriculture.

[3] Sundays and Mondays are close seasons for ducks and other waterfowl.

	Open seasons.
Oregon (1909–1913):	
District No. 1.[1]—	
Male deer	Aug. 1–Nov. 1.
Female deer and spotted fawn, moose, elk, antelope, caribou, sheep, goat	No open season.
Silver gray squirrel	Oct. 1–Nov. 1.
Quail, grouse, male Chinese pheasant (except in Coos, Curry, Jackson, and Josephine Counties, no open season)	Oct. 1–Nov. 1.
Pheasant (silver, golden, Reeves, and English), Hungarian partridge, bobwhite, prairie chicken, Franklin grouse, foolhen, wild turkey, plover (semipalmated, snowy), sandpiper (Least, western, solitary), and swan	No open season.
Dove, wild pigeon	Sept. 1–Nov. 1.
Plover, snipe, yellowlegs	**Nov. 1–Dec. 16.**[2]
Rail, coot, gallinule	**Nov. 1–Dec. 1.**[2]
Duck, goose[3]	**Nov. 1–Dec. 16.**[2]
Brant	**Sept. 16–Dec. 16.**
District No. 2.—Open seasons same as in district No. 1, except as follows:	
Silver gray squirrel	No open season.
Quail, pheasant	No open season.
Dove	Sept. 1–Nov. 1.
Ruffed grouse, native pheasant, blue or sooty grouse	Sept. 1–Nov. 1.
Sage hen	Aug. 1–Sept. 1.
Black-breasted and golden plover, jacksnipe or Wilson snipe, yellowlegs, duck, goose	**Sept. 15–Dec. 16.**
Rail, coot	**Sept. 15–Dec. 1.**
Pennsylvania (1909–1913):[4]	
Deer—male with horns 2 inches above the hair	Nov. 10–26.
Elk	Nov. 15, 1921.
Bear	Oct. 1–Jan. 1.
Hare, rabbit	Nov. 1–Jan. 1.
Squirrel (gray, black, fox)	Oct. 15–Dec. 1.
Raccoon	Sept. 1–Jan. 1.
Quail	Nov. 1–Dec. 16.
Ruffed grouse, imported pheasants (Chinese, English), Hungarian partridge, woodcock	Oct. 15–Dec. 1.
Wild turkey	May 8, 1915.
Dove, blackbird, killdeer plover	No open season.
Black-breasted and golden plover, jacksnipe or Wilson snipe, yellowlegs	**Sept. 1–Dec. 16.**
Upland or grass plover, reedbird (Federal Regulations Nos. 3 and 4)	**Sept. 1, 1918.**
Rail, coot, mud hen, gallinule	**Sept. 1–Dec. 1.**
Wild waterfowl—duck, goose, brant, loon, grebe	**Sept. 1–Dec. 16.**
Rhode Island (1900–1913):	
Deer[5]	No open season.
Gray squirrel, hare, rabbit	Nov. 1–Jan. 1.
Quail or bobwhite, ruffed grouse or partridge	Nov. 1–Jan. 1.
Dove	No open season.
Pheasant, Hungarian partridge	Oct. 15, 1920.
Woodcock	Nov. 1–**Dec. 1.**
Plover, yellowlegs, snipe	July 15–Dec. 16.
Duck, goose, brant	Aug. 15–**Dec. 16.**
Rail, coot, gallinule	**Aug. 1–Dec. 1.**
South Carolina (1902–1912):	
Deer (except Berkeley County, Aug. 1–Feb. 1)	Sept. 1–Jan. 1.
Quail (partridge), wild turkey (except Berkeley County, Nov. 1–Apr. 1)	Nov. 15–Mar. 15.
Dove	Aug. 15–Mar. 1.
Woodcock	**Sept. 1–Jan. 1.**
Wood duck	**Sept. 1–Feb. 1.**

[1] District No. 1, west of Cascades, includes Benton, Clackamas, Clatsop, Columbia, Coos, Curry, Douglas, Jackson, Josephine, Lane, Lincoln, Linn, Marion, Multnomah, Polk, Tillamook, Washington, Yamhil. Counties. District No. 2, east of Cascades, includes the other counties in the State.

[2] In Clatsop, Columbia, Coos, Multnomah, and Tillamook Counties the season opens Sept. 15.

[3] Unlawful to kill geese at any time on islands or sand bars in the Columbia River east of the Cascades or on Deschutes and John Day Rivers south to junction with White River and Thirtymile Creek, respectively.

[4] Game birds or animals reared in captivity may be killed at any time.

[5] Tame deer kept in confinement may be killed by the owner at any time, or any deer injuring crops, by the owner or occupant of the premises, under permit from secretary of state.

South Carolina—Continued.	*Open seasons.*
Grackle	**Oct. 1–Mar. 1.**
Duck (except wood duck), goose, brant	**Nov. 1–Feb. 1.**
Black-breasted and golden plover, jacksnipe or Wilson snipe, yellowlegs	**Sept. 1–Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
South Dakota (1909–1913):	
Deer (except fawns, no open season)	Nov. 1–Dec. 1.
Elk, antelope, mountain sheep	No open season.
Quail, dove	No open season.
Partridge, grouse, prairie chicken, woodcock, golden plover, upland plover, snipe	Sept. 10–Oct. 10.
Introduced pheasant	Jan. 1, 1915.
Ducks, goose, brant, any aquatic fowl	**Sept. 10–Dec. 16.**
Yellowlegs	**Sept. 10–Dec. 16.**
Tennessee (1903–1913):	
Deer (except Fentress County, Dec. 1–Jan. 1)	Oct. 1, 1915.
Squirrel	June 1–Mar. 1.[1]
Quail or partridge (except Haywood County, Dec. 1–Feb. 1; Washington and Unicoi Counties, Mar. 27, 1918)	Nov. 15–Mar. 1.
Grouse, pheasant (except English or ringneck pheasants), wild turkey[2]	Nov. 1–Mar. 1.
Pheasant, English or ringneck	Dec. 1–Jan. 1.
Dove (except in Shelby County, Mar. 1–July 15)	Aug. 1–Apr. 15.
Marsh blackbird	Oct. 1–Apr. 15.
Woodcock	**Oct. 1–Jan. 1.**
Black-breasted and golden plover, Wilson or jacksnipe, yellowlegs	**Oct. 1–Dec. 16.**
Rail, coot, mud-hen	**Oct. 1–Dec. 1.**
Duck (except teal and wood duck, Aug. 1–Jan. 16), goose, brant	**Oct. 1–Jan. 16.**
Texas (1907–1911):	
Deer (female deer and spotted fawn no open season)	Nov. 1–Jan. 1.
Antelope, sheep, 5 years	Nov. 1, 1916.
Quail or partridge, dove	Nov. 1–Feb. 1.
Prairie chicken or pinnated grouse, pheasants (Mongolian, English), 5 years	Nov. 1, 1916.
Wild turkey	Dec. 1–Apr. 1.
Woodcock	**Nov. 1–Jan. 1.**
Black-breasted and golden plover, Wilson or jacksnipe, yellowlegs	**Sept. 1–Dec. 16.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, goose, brant	**Oct. 1–Jan. 16.**
Utah (1909-1913):	
Deer (except in Tooele County Oct. 1, 1918, and except as below)	Oct. 1–Oct. 16.
Exception: Nonresident not permitted to kill deer.	
Elk, antelope, sheep	No open season.
Quail, prairie chicken, pheasants (Chinese, English, Mongolian) dove, robin, shore bird (except snipe), swan (see exceptions)	No open season.
Exceptions: Quail in Garfield, Kane, and Washington Counties	Sept. 1–Feb. 1
Quail in Carbon, Davis, Salt Lake, San Pete, Sevier, Uinta, Utah, and Weber Counties	Oct. 1–Nov. 1
Iron County	Oct. 1–Dec. 1.
Grouse	Oct. 6–Oct. 16.
Sage hen	Aug. 15–Nov. 1.
Black-breasted and golden plover, yellowlegs	**Sept. 1–Dec. 16.**
Snipe	Oct. 1–Dec. 16.
Duck, goose	Oct. 1–Jan. 1.
Rail, coot, gallinule	**Sept. 1–Dec. 1.**

[1] *Special squirrel seasons:* Benton, Decatur, Wilson, June 1–Jan. 1; Carroll, June 15–Mar. 1; Carter, July 15–Mar. 1; Crockett, Weakley, July 1–Feb. 1; Dyer, June 1–July 1 and Oct. 1–Jan. 1; Fayette, July 15–Jan. 1; Gibson, Sevier, June 1–Feb. 1; Hardeman, July 15–Feb. 15; Haywood, June 15–Jan 1; Henderson July 15–Jan. 15; McNairy, Madison, July 1–Mar. 1; Robertson, July 1–Jan. 1; Shelby, June 15–Feb. 1; Stewart, Aug. 1–Feb. 1; Warren, Oct. 1–Mar. 1. Bedford, Blount, Cannon, Clay, Coffee, Cumberland, Dickson, Fentress, Giles, Greene, Hickman, Humphreys, Jackson, Knox, Lawrence, Lincoln, London, Marshall, Maury, Meigs, Moore, Overton, Perry, Pickett, Putnam, Rhea, Sequatchie, Sullivan, Van Buren, Washington, Wayne, White, Williamson, unprotected.

In Chester, Dyer, Hardeman, Hardin, and McNairy Counties anyone may kill squirrels on his own property at any time for his own use.

[2] *Special wild turkey seasons:* Dyer (gobblers), Nov. 1–May 1 (hens), Nov. 1–Feb. 1; Clay, Fentress, Overton, Pickett, Aug. 1–May 1; Lauderdale, Feb. 15, 1915.

	Open seasons.
Vermont[1] (1894–1913):	
Deer with horns not less than 3 inches long[2] (no open season for others)	Nov. 10–Dec. 2.
Moose, caribou	No open season.
Elk, 10 years	Feb. 20, 1923.
Hare, rabbit	Sept. 15–Mar. 1.
Gray squirrel	Sept. 15–Dec. 1.
Quail, ruffed grouse (partridge), woodcock	Sept. 15–Dec. 1.
Pheasant, European partridge, dove, upland plover, wood duck, swan	No open season.
Plover (except upland plover), English snipe, yellowlegs	Sept. 1–Dec. 1.
Duck (except wood duck), goose, brant	**Sept. 1–Dec. 16.**
Coot, gallinule	**Sept. 1–Dec. 1.**
Virginia[3] (1903–1912):	
Deer (except in Brunswick and Greenesville Counties, Oct. 1–Feb. 1)	Sept. 1–Dec. 1.
Rabbit	Nov. 1–Feb. 1.[4]
Squirrel:	
Brunswick and Greenesville Counties	Nov. 1–Feb. 1[5]
Isle of Wight and Southampton Counties (gray or fox)	Sept. 1–Jan. 15
Warren County	Nov. 15–Jan. 1
Opossum in Halifax County	Oct. 15–Feb. 1
Quail or partridge, pheasant or grouse, wild turkey (see exception)	Nov. 1–Feb. 1.
Exception: West of the Blue Ridge	Nov. 1–Jan. 1
Dove in Brunswick and Greenesville Counties	Aug. 15–Jan. 15.
Woodcock	Nov. 1–**Jan. 1.**
Black-breasted and golden plover	**July 20–Dec. 16.**
Jacksnipe or Wilson snipe, yellowlegs	**Sept. 1–Dec. 16.**
Rail, coot, mud hen, gallinule	**July 20–Dec. 1.**
Summer or wood duck	Aug. 1–Jan. 1.
Winter waterfowl[6] **(except in Brunswick and Greenesville Counties, Aug. 1–Jan. 1)**	**Oct. 15–Feb. 1.**
Washington[7] (1903–1913):	
Deer (except Okanogan County, Sept. 1–Nov. 1), sheep, goat	Oct. 1–Dec. 1.
Male moose and elk, 12 years	Oct. 1, 1925.
Antelope (males only)	Sept. 15–Nov. 1.
Moose, caribou, spotted fawn, and females of deer, elk, antelope	No open season.
Quail, ruffed grouse, grouse, prairie chicken, pheasant, and other imported upland game birds (see exceptions)	Oct. 1–Dec. 1.
Exceptions:	
East of Cascades, Chinese pheasant (except in Kittitas and Yakima Counties, Oct. 1–16), native pheasant, prairie chicken	Sept. 15–Nov. 1.
Blue grouse	Sept. 1–Dec. 1.
Quail east of Cascades (except in Spokane County)	Oct. 1, 1915.
Western and eastern, prairie chicken, native pheasant, ruffed grouse, Hungarian partridge, bobwhite quail, scaly partridge, sage hen, in Kittitas and Yakima Counties	Oct. 1, 1915.
California quail in Kittitas and Yakima Counties, Chinese pheasant in Asotin County, and quail, any species of partridge, sage hen, and imported game birds in Okanogan County	Oct. 1, 1915.
Blue grouse West of Cascades	Sept. 16–Oct. 1.
Sage grouse, sage hen, band-tailed pigeon, wood duck, and in the counties of Island, King, Pierce, San Juan, Skagit, Snohomish, and Whatcom ruffed grouse	No open season.
Hungarian partridge	Oct. 1, 1920.
Dove (except east of Cascades, Sept. 15–Nov. 1), swan	No open season.
Blackbreasted and golden plover, jacksnipe or Wilson snipe, yellowlegs	Oct. 1–**Dec. 16.**[8]
Duck, goose, brant	Oct. 1–**Jan. 16.**[8]
Rail	Oct. 1–**Dec. 1.**[8]
Coot and gallinule	**Sept. 1–Dec. 1.**

[1] The governor is authorized to suspend open seasons in time of drought and fix another open season for deer in such event.

[2] Deer kept in private game preserves may be killed by the owners at any time.

[3] Boards of supervisors may shorten the open seasons in their counties and make other restrictions not repugnant to law, "and may include in such protection other game not specifically mentioned in this section." Code 1904, sec. 2070a, as amended in 1906.

[4] Residents of the State may kill rabbits on their own lands at any time.

[5] Residents of State may kill squirrels on their own lands at any time.

[6] Wildfowl can not be hunted on Wednesdays and Saturdays on Back Bay, Princess Anne County.

[7] On Mercer Island and shores of Lake Washington game animals and birds are protected all the year.

[8] The season opens Sept. 15 in Adams, Douglas, Ferry, Grant, Lincoln, Okanogan, Spokane, Stevens, and Whitman Counties.

	Open seasons.
West Virginia (1909–1913):	
Deer (with horns more than 4 inches long—no open season for other deer)	Oct. 15–Dec. 1.
Elk	1928.
Squirrel (gray, black, red, fox)	Sept. 1–Dec. 1.
Quail (Virginia partridge)	Nov. 1–Dec. 1.
Ruffed grouse (pheasant), wild turkey	Oct. 15–Dec. 1.
Pheasants (English, Chinese, Reeves, Lady Amherst), capercailzie, or any other introduced foreign game bird, dove, wood duck	No open season.
Black-breasted and golden plover	July 15–**Dec. 16.**
Jacksnipe or Wilson snipe	Oct. 15–**Dec. 16.**
Yellowlegs	**Sept. 1–Dec. 16**
Woodcock	July 15–Dec. 20.
Rail (ortolan)	July 15–**Dec. 1.**
Coot, gallinule	**Sept. 1–Dec. 1.**
Duck (except wood duck, no open season), goose, brant	Sept. 1–**Jan. 16.**
Wisconsin (1898–1913):	
Deer (see exceptions)	Nov. 11–Dec. 1.
Exceptions: Wood County, 3 years	Nov. 10, 1916
Adams, Brown, Buffalo, Calumet, Columbia, Crawford, Dane, Dodge, Door, Fond du Lac, Grant, Green, Green Lake, Iowa, Jefferson, Kenosha, Kewaunee, La Crosse, Lafayette, Manitowoc, Marquette, Milwaukee, Monroe, Outagamie, Ozaukee, Pepin, Portage, Racine, Richland, Rock, Sauk, Sheboygan, Vernon, Walworth, Washington, Waukesha, Waupaca, Waushara, and Winnebago Counties	No open season
Elk, moose	No open season.
Rabbit, in Eau Claire, Pierce, Portage, Richland, Vernon, Waupaca, and Waushara Counties	Sept. 10–Feb. 1.
In Dane, Dunn, Green, Green Lake, Jefferson, Juneau, La Crosse, Outagamie, Marinette, Rock, Trempealeau, Walworth, and Wood Counties	Oct. 10–Feb. 1.
Squirrel (gray, fox, black, see exceptions)	Oct. 10–Feb. 1.
Exceptions: Eau Claire, Pierce, Portage, Richland, Vernon, Waupaca, and Waushara Counties	Sept. 10–Feb. 1
Waukesha County	No open season.
Quail, pheasants (Chinese, English, Mongolian), 8 years	Oct. 1, 1915.
Partridge	Oct. 1–Dec. 1.
Prairie chicken, grouse: In Adams, Ashland, Barron, Bayfield, Brown, Burnett, Buffalo, Chippewa, Clark, Crawford, Dodge, Douglas, Dunn, Eau Claire, Fond du Lac, Grant, Green Lake, Iowa, Jackson, Juneau, Lafayette, Marathon, Marinette, Marquette, Monroe, Oconto, Outagamie, Pepin, Pierce, Polk, Portage, Richland, Rusk, St. Croix, Sawyer, Shawano, Vernon, Washburn, Waupaca, Waushara, and Wood Counties	Sept. 7–Oct. 2.
Prairie chicken, grouse: In rest of State	Sept. 1, 1915.
Dove, swan	No open season.
Woodcock, plover, snipe	Sept. 7–Dec. 1.
Coot or mud hen, rail, rice hen, duck, goose, brant	Sept. 7–Dec. 1.
Wyoming (1909–1913):	
Deer (does and fawns, no open season) exceptions	Oct. 1–Nov. 1.
Exceptions: Fremont, Lincoln, and Park Counties	Sept. 1–Nov. 16.
Elk and male sheep in Lincoln, Park, and Fremont Counties north of Big Wind River and Bad Water Creek and also in Fremont County south of Sweetwater River	Sept. 1–Nov. 16.
Elk and sheep in rest of State, moose, antelope, 5 years	Sept. 1, 1918.
Quail (except in Crook County, Sept. 25, 1917), Mongolian pheasant	Sept. 25, 1915.
Grouse (other than sage grouse), see exceptions	Sept. 15–Nov. 16.
Exceptions: All grouse in Albany, Carbon, Laramie, and Sweetwater Counties	July 15–Sept. 1.
Sage grouse (except in Sheridan County, Aug. 1, 1915)	Aug. 1–Sept. 1.
Dove, swan	No open season.
Black-breasted and golden plover, jacksnipe or Wilson snipe, yellowlegs	Sept. 1–**Dec. 16.**
Curlew (Regulation No. 4)	**Sept. 1, 1918.**
Rail, coot, gallinule	**Sept. 1–Dec. 1.**
Duck, goose, **brant**	Sept. 1–**Dec. 16.**
Alberta[1] (1906–1913):	
Deer, moose, caribou	Nov. 1–Dec. 15.
Antelope (male)	Oct. 1.–Nov. 1.
Elk or wapiti	Nov. 15, 1915.
Buffalo, female deer, moose, antelope, sheep, and young of all big game	No open season.
Sheep (male), goat	Sept. 1–Oct. 15.

[1] North of latitude 55° any game animal or bird, except elk and buffalo, may be killed at any time if needed for food.

	Open seasons.
Alberta—Continued.	
Partridge (except Hungarian partridge, no open season), grouse, prairie chicken, ptarmigan, pheasant (except English, no open season)	Oct. 1–Nov. 1.
Plover, curlew, sandpiper, snipe, shore bird, coot, rail, crane	Sept. 1–Jan. 1.
Duck,[1] swan	Aug. 23–Jan. 1.
British Columbia[2] (1898–1913):	
Deer, goat	Sept. 1–Dec. 15.
Bull moose, bull caribou, hare	Sept. 1–Jan. 1.[2]
Sheep, rams only	Sept. 1–Nov. 15.[2]
Buffalo, elk, and young of deer and females and young of moose, caribou, and sheep	No open season.
Bear	Sept. 1–July 15.
Quail, grouse, ptarmigan, English partridge, prairie chicken, pheasant, black game, capercailzie, snipe, duck, goose, swan	No open season.[3]
Plover, bittern, heron, meadowlark	Sept. 1–Mar. 1.
Manitoba (1909–1913):[3]	
Deer, elk or wapiti, moose, caribou or reindeer, antelope or cabri (males)	Dec. 1–Dec. 15.
Females and young of foregoing species and bison or buffalo	No open season.
Quail, woodcock, plover (except upland plover, July 1–Jan. 1), sandpiper, snipe	Aug. 1–Jan. 1.
Partridge, prairie chicken, grouse	Oct. 1–Oct. 20.
Dove	No open season.
Pheasant, 11 years	Oct. 1, 1920.
Duck	Sept. 1–Dec. 1.
New Brunswick (1909–1913):	
Deer, moose, caribou (cow and calf[4] moose and caribou, no open season)	Sept. 15–Dec. 1.
Partridge, woodcock, snipe	Sept. 15–Dec. 1.
Pheasant	No open season.
Teal, wood duck, dusky or black duck, goose, brant	Sept. 1–Dec. 2.
Shore or other birds on beaches, islands or lagoons bordering tidal waters of Northumberland Strait, Gulf of St. Lawrence, and Bay of Chaleur	Aug. 15–Jan. 1.
Newfoundland[5] (1902–1913):	
Elk, moose	No open season.
Caribou (except in a special region near Grand Lake, no open season)	Oct. 21–Feb. 1.[6]
Ptarmigan, willow grouse or partridge, plover, curlew, snipe, or "other wild or migratory birds (except wild geese)"	Sept. 20–Jan. 1.
Capercailzie, black game, 10 years	Oct. 12, 1917.
Nova Scotia (1908–1912):	
Deer, 3 years	Oct. 1, 1915.
Moose, bulls only (see exception)	Sept. 16–Nov. 16.
Exception: Cape Breton Island	Sept. 16, 1915
Caribou (see exceptions)	Sept. 16, 1915.
Exceptions: Inverness and Victoria Counties, bulls only	Sept. 16–Oct. 16
Hare, rabbit	Oct. 1–Mar. 1.
Quail, sharp-tailed grouse, ptarmigan, plover, curlew, yellow legs, sandpiper, teal, heron, bittern, beach birds, and waders	Aug. 15–Mar. 1.
Ruffed grouse or birch partridge	Oct. 1–Nov. 1.
Canada grouse (spruce partridge), chukar partridge, pheasant, capercailzie, black game	No open season.
Woodcock, Wilson snipe, blue-winged duck, wood duck	Sept. 1–Mar. 1.
Ontario[7] (1907–1913):	
Deer (except in Dufferin, Grey, Simcoe, and Wellington Counties, to Nov. 1, 1914; in Bruce County, Nov. 1, 1916; and except fawns, no open season)	Nov. 1–Nov. 16.[8]
Elk or wapiti	No open season.

[1] Except white-winged scoters, north of township 50, which may be taken at any time.

[2] The lieutenant governor in council is empowered to open seasons each year for Columbian deer, quail, grouse, ptarmigan, English partridge, prairie chicken, pheasant, capercailzie, black game, snipe, duck, and goose. Orders in council have been made closing the season throughout the year on deer on the Queen Charlotte Islands; on white-tailed deer in the Similkameen and Okanogan districts; on moose south of latitude 52° except in the Columbia district of East Kootenay; and on mountain sheep in the Yale, Okanogan, and Similkameen districts.

[3] North of parallel 54° any game except pheasants may be taken at any time by settlers, farmers, surveyors, prospectors, explorers, or Indians in actual need of food, but not for sale or barter.

[4] Under 3 years of age and with horns bearing less than 3 tines 4 inches in length.

[5] Poor settlers may kill any birds, except capercailzie and black game, at any time, for immediate consumption by themselves or their families.

[6] Additional open season Aug. 1–Oct. 1.

[7] Lieutenant governor in council may alter close seasons in region north and west of French River, Lake Nipissing, and Mattawa River, and in the vicinity of Rondeau Park and close for a definite period seasons for any game animal or nonmigratory game bird whose numbers have diminished.

[8] Persons who put deer on their own lands, and their licensees, may hunt such deer Oct. 1–Nov. 16.

	Open seasons.
Ontario—Continued.	
Moose, caribou (bulls only)	Oct. 16–Nov. 16.[1]
Hare [2]	Oct. 1–Dec. 16.
Squirrel (black or gray) (except in Norfolk County, Nov. 15, 1915)	Nov. 15–Dec. 2.
Quail, wild turkey	Nov. 15–Dec. 2.
Partridge, grouse, prairie fowl, pheasant (see exceptions)	Oct. 15–Nov. 16.
Exceptions: Essex County, ruffed grouse, English ring neck pheasant, Hungarian partridge	Oct. 15, 1914
Lincoln and Welland Counties, English or Mongolian pheasant	Oct. 15, 1914
Capercailzie	Sept. 15, 1915.
Dove	No open season.[3]
Woodcock	Oct. 1–Nov. 16.
Plover, snipe, rail, other shore birds, duck and other waterfowl	Sept. 1–Dec. 16.[4]
Prince Edward Island (1906–1911):	
Hare, rabbit	Nov. 1–Feb. 1.
Partridge	Oct. 15–Nov. 15.
Plover, curlew	Aug. 1–Jan. 1.
Snipe, woodcock	Sept. 1–Jan. 1.
Yellow legs, shore and other birds along beaches or tidal marshes, duck	Aug. 20–Jan. 1.
Goose	Sept. 15–May 10.
Brant	Apr. 20–Jan. 1.
Quebec (1899–1913):	
Zone 1.[5] Deer, moose (see exceptions)	Sept. 1–Jan. 1.
Exceptions: In Labelle, Ottawa, Pontiac, and Temiscaming Counties. Oct. 1–Dec. 1	
Cow moose and young deer and moose	No open season.
Caribou (young, no open season)	Sept. 1–Feb. 1.
Hare	Oct. 15–Feb. 1.
Bear	Aug. 20–July 1.
Birch or swamp partridge	Sept. 1–Dec. 15.
White partridge or ptarmigan	Nov. 1–Feb. 1.
Woodcock, plover, curlew, tattler, sandpiper, snipe	Sept. 1–Feb. 1.
Widgeon, teal, duck (except sheldrake), gull, loon	Sept. 1–Mar. 1.[6]
Zone 2. Close seasons same as in Zone 1, except as follows:	
Caribou	Sept. 1.–Mar. 1.
Hare	Oct. 15–Mar. 1.
Birch or swamp partridge	Sept. 15–Feb. 1.
White partridge or ptarmigan	Nov. 15–Mar. 1.
Saskatchewan [7] (1905–1913):	
Deer, elk or wapiti, moose, caribou (males only)	Nov. 15–Dec. 1.[8]
Antelope (males only)	Oct. 1–Nov. 15.
Buffalo and females and young of above big game	No open season.
Partridge, pheasant, prairie chicken, grouse, ptarmigan	Sept. 15–Nov. 16.
English pheasant	No open season.
Plover, curlew, sandpiper, snipe, shore birds, coot, rail, duck, goose, swan, crane	Sept. 15–Jan. 1.
Northwest Territories [9] (1906):	
Deer, elk or wapiti, moose, caribou, goat, sheep	Dec. 1–Apr. 1.[10]
Musk ox	Oct. 15–Mar. 20.
Partridge, prairie chicken, grouse, pheasant	Sept. 1–Jan. 1.
Duck, goose, swan	Sept. 1–Jan. 15.
Yukon [11] (1902–1906):	
Deer, elk or wapiti, moose, caribou, sheep, goat, musk ox (males only)	Sept. 1–Mar. 1.
Bison or buffalo	No open season.
Partridge, prairie chicken, grouse, ptarmigan, pheasant	Sept. 1–Mar. 15.
Sandpiper, snipe, crane, duck, goose, swan	Aug. 10–June 1.

[1] South of the Canadian Pacific R. R., between Mattawa and the Manitoba boundary, Nov. 1–16.

[2] Cottontail rabbits (wood hares) may be killed during close season when damaging trees or shrubs.

[3] Under act for protection of insectivorous birds, Rev. Stats., 1897, ch. 289, sec. 3.

[4] Shore birds and waterfowl south of the Canadian Pacific, between Montreal and Toronto, and the Guelph and Goderich Railways, Sept. 15–Dec. 16.

[5] Zone No. 1 comprises the whole Province, except that part of the counties of Chicoutimi and Saguenay east and north of the River Saguenay. Zone No. 2 comprises the excepted part of said counties.

[6] Inhabitants of Zone 2 and Gaspé County may take these birds for food Aug. 1–June 1.

[7] Lieutenant governor in council may extend close seasons over current year, within limits, on petition of six game guardians.

[8] Applies north of line between Townships 34 and 35; south of said line, no open season.

[9] Indians, inhabitants, travelers, explorers, and surveyors in need of food exempt. Governor in council may alter seasons.

[10] Also July 15–Oct. 1.

[11] Indians, explorers, surveyors, prospectors, miners, and travelers in need of food are exempt. Commissioner in council may alter seasons.

SHIPMENT OF GAME.

Shipment is the most important feature of the traffic in game. If permitted without limitation it is a great factor in game destruction. A realization of this fact has induced many of the States to prohibit export of all or certain kinds of game, and in a few instances all transportation even within the State. The subject may be conveniently considered under the following subheads: "Federal laws," and "State laws prohibiting export."

FEDERAL LAWS.

Federal laws affecting the shipment of game comprise the statutes regulating interstate commerce in game and the importation of birds from foreign countries, and those providing for the protection of birds and game on territory under immediate Federal jurisdiction.

They comprise: (1) Sections 241 to 244 of the Criminal Code (35 Stat., 1137), regulating the importation and interstate shipment of game;[1] (2) the tariff act, imposing duties on game, skins, and feathers imported from foreign countries; (3) the act regulating the introduction of eggs of game birds; (4) the game law of Alaska; and (5) provisions for protecting birds in the national parks,[2] national forests, and other Government reservations. These laws are more fully discussed in Bulletin No. 16 of the Biological Survey, entitled "Digest of Game Laws for 1901" (pp. 69–79). The full text of the new Alaskan game law of 1908, with the regulations now in force, is published in circulars of the Biological Survey. Sections 241, 242, 243, and 244 of the Criminal Code of the United States are as follows:

SEC. 241. The importation into the United States, or any Territory or District thereof, of the mongoose, the so-called "flying foxes" or fruit bats, the English sparrow, the starling, and such other birds and animals as the Secretary of Agriculture may from time to time declare to be injurious to the interests of agriculture or horticulture, is hereby prohibited; and all such birds and animals shall, upon arrival at any port of the United States, be destroyed or returned at the expense of the owner. No person shall import into the United States or into any Territory or District thereof, any foreign wild animal or bird, except under special permit from the Secretary of Agriculture: *Provided*, That nothing in this section shall restrict the importation of natural history specimens for museums or scientific collections, or of certain cage birds, such as domesticated canaries, parrots, or such other birds as the Secretary of Agriculture may designate. The Secretary of the Treasury is hereby authorized to make regulations for carrying into effect the provisions of this section.

SEC. 242. It shall be unlawful for any person to deliver to any common carrier for transportation, or for any common carrier to transport from any State, Territory, or District of the United States, to any other State, Territory, or District thereof, any foreign animals or birds, the importation of which is prohibited, or the dead bodies or parts thereof of any wild animals or birds, where such animals or birds have been

[1] These sections are sections 2, 3, and 4 of the Lacey Act as amended.

[2] The law governing the Yellowstone Park prohibits any person, or any stage, express, or railway company from receiving for transportation animals, birds, or fish taken in the park, under a penalty not exceeding $300. (28 Stat., ch. 72, sec. 4.)

killed or shipped in violation of the laws of the State, Territory, or District in which the same were killed, or from which they were shipped: *Provided*, That nothing herein shall prevent the transportation of any dead birds or animals killed during the season when the same may be lawfully captured, and the export of which is not prohibited by law in the State, Territory, or District in which the same are captured or killed: *Provided further*, That nothing herein shall prevent the importation, transportation, or sale of birds or bird plumage manufactured from the feathers of barnyard fowls.

SEC. 243. All packages containing the dead bodies, or the plumage, or parts thereof, of game animals, or game or other wild birds, when shipped in interstate or foreign commerce, shall be plainly and clearly marked, so that the name and address of the shipper, and the nature of the contents, may be readily ascertained on an inspection of the outside of such package.

SEC. 244. For each evasion or violation of any provision of the three sections last preceding, the shipper shall be fined not more than two hundred dollars; the consignee knowingly receiving such articles so shipped and transported in violation of said sections shall be fined not more than two hundred dollars; and the carrier knowingly carrying or transporting the same in violation of said sections shall be fined not more than two hundred dollars.

STATE LAWS PROHIBITING EXPORT.

Since the constitutionality of the Connecticut statute prohibiting export of certain game was established by the supreme court in 1896,[1] nonexport laws have been generally adopted, and at the present time every State prohibits the export of certain kinds of game. In most States sportsmen are allowed to carry a limited amount of game out of the State under special restrictions, and exceptions to the laws prohibiting export are also made in the case of birds and animals intended for propagation or reared in licensed preserves.

Restrictions on shipment from the State have now become so stringent that all the States west of the Mississippi River, prohibit export of all game protected by local laws. East of the Mississippi, laws prohibiting the export of all game, or, in some cases, all but one or two unimportant species, are in force in all the States except Kentucky and a small group along the coast from Massachusetts to North Carolina.

Special attention is called to the following table, which contains a list of the game prohibited from export by each State:

Export of game prohibited.

Alabama: All protected game.

Exceptions: Nonresident licensee may take with him or have carried to him, openly, game lawfully killed by him. State game and fish commissioner may issue $1 permit to any person to capture, kill, or export not more than 10 pairs of any one species of game or birds for scientific or propagating purposes.

Alaska: Deer, moose, caribou, sheep, goat, bear, or hides of these animals; wild birds, except eagles, or any parts thereof.

Exceptions: Specimens may be exported under restrictions imposed by the Secretary of Agriculture, and trophies of big game under licenses issued by the governor.[2]

Arizona: All protected game.

Exceptions: Deer or wild turkey may be exported under a $2 permit.

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[1] Geer *v.* Conn., 161 U. S., 519.

[2] See p. 54 and also circulars of the Biological Survey, U. S. Department of Agriculture.

Arkansas: Deer (unless raised in captivity), wild turkey, wild fowl, game of any description except rabbits, which must be shipped open to view. (Squirrels can not be shipped out of Craighead, Dallas, Lafayette, and White Counties.) Local exceptions in Clay and Mississippi Counties.

California: All protected game.

Colorado: All protected game.

Exceptions: Game may be exported under permit from game commissioner if permit be attached and package plainly marked so as to show nature of contents. The following fees are charged for export permits: Elk, $10; deer, $5; sheep, $5; bird, 25 cents—in each case the edible portion alone.

Connecticut: Quail, ruffed grouse, woodcock.

Delaware: Rabbit, quail, partridge, woodcock. Squirrel, dove, rail, reedbird, goose, brant, for sale.

Exceptions: Holder of license may export 10 rabbits, 10 squirrels, 50 reedbirds, 50 rail, and 20 birds or fowl of any other species a week, lawfully killed by himself, under affidavit that the game is not for sale.

Florida: All protected game.

Exceptions: Nonresident licensee may carry out game as personal baggage; 10 pairs of any species of game birds may be exported for scientific or propagating purposes under $1 permit.

Georgia: All protected game from county or State.

Exception: Licensee may export game lawfully killed.

Idaho: All protected game.

Exceptions: Any hunter may export, under hunting license, big game lawfully taken, under a 50-cent permit obtained from a justice of the peace, probate judge, game warden, or deputy game warden on a sworn statement to issuing officer that game was not procured contrary to law. Mounted heads and stuffed birds legally secured may be exported.

Illinois: All protected game except dove, coot, rail taken in State.

Exceptions: Game may be exported under license from the State. Nonresident may take from State 50 birds killed by himself, if carried openly for inspection.

Indiana: Deer, quail, grouse, prairie chicken, pheasant, wild turkey, woodcock, duck, goose, brant, and other waterfowl.

Exception: Nonresident may take from State 15 birds killed by himself, if carried openly for inspection together with his license, or 45 if he has hunted for 3 or more days consecutively.

Iowa: All protected game.

Exception: Nonresident may take from State not more than 25 game birds or animals, if carried openly for inspection, and if hunting license be shown on request.

Kansas: All protected game.

Kentucky: Quail, partridge, grouse, pheasant, wild turkey killed in the State.

Louisiana: All protected game.

Exception: A nonresident licensee may carry with him out of the State, under his license, one day's bag limit of game, if not for sale. Game raised in private preserves and properly tagged may also be exported.

Maine: All protected game.

Exceptions: A resident of the State may export 1 deer in a season if open to view, tagged to show name and address of owner and accompanied by him, and under shipping license 1 moose, 5 partridges, 10 woodcock, and 10 ducks lawfully killed by himself. A nonresident may export under hunting license 1 moose and 2 deer lawfully killed by himself and may take home 10 partridges, 15 ducks, and 10 woodcock; he may also ship out one pair of game birds a month under a special 50-cent license. Live game may be exported for breeding, scientific, or advertising purposes, under permit of the commissioners of inland fisheries and game.

Maryland: *County provisions, as follows:*

Allegany—Deer, squirrel, rabbit, partridge or quail, pheasant, English pheasant, turkey, dove, woodcock from county (for sale).

Anne Arundel—All protected game, viz: Squirrel, rabbit, quail, partridge, pheasant, woodcock, snipe, plover, duck, goose, brant, swan from county.

Baltimore—Rabbit, squirrel, quail, partridge, pheasant, dove, woodcock from county.

Calvert—Rabbit, partridge, woodcock from county (for sale, barter, or trade).

Caroline—Rabbit, quail, partridge, woodcock from county.

Cecil—Squirrel, quail, grouse, woodcock, plover from county.

Dorchester—Squirrel, rabbit, quail, partridge, woodcock, dove (for sale).

Exception: Twelve quail or partridges, 6 squirrels, rabbits, woodcock, and doves may be taken out of the county at one time as personal baggage, if carried openly and not intended for sale.

Frederick—Squirrel, partridge, pheasant, woodcock from county (for sale).

Garrett—Rabbit, partridge, pheasant, wild turkey, woodcock from State.

Exception: Nonresident may take out game killed under his hunting license.

Kent—Squirrel, rabbit, and all birds from county (for sale, except under license).

Montgomery—Rabbit, partridge, quail, woodcock from county (for sale).

Queen Anne—Rabbit, partridge, woodcock from county (for sale).

Somerset—All game, viz: Squirrel, rabbit, quail or partridge, pheasant, dove, woodcock, duck, goose from county.

Washington—Deer, squirrel, rabbit, partridge, pheasant, dove, woodcock, turkey from county (for sale).

Wicomico—Quail or partridge from Wicomico and Worcester Counties considered as one territory.

Worcester—Rabbit, quail, woodcock from county.

Massachusetts: Quail, ruffed grouse, woodcock taken in State; other game illegally taken in State.

Exceptions: Nonresident may take 10 wild fowl or birds of all kinds out of the State under his hunting license. Quail reared in captivity under permit may be exported for propagation.

Michigan: All protected game.

Exceptions: (1) Deer may be transported outside the State to reach a point within the State.

(2) Nonresident licensee may take out, as hand baggage, 1 day's bag limit of birds, and may ship 1 deer under permit.

(3) Landowners and members of clubs owning game preserves may ship during open season under a $10 permit from State warden 20 ducks or other migratory birds killed by them on their own premises.

(4) Game reared in captivity and deer skins and green or mounted buck-deer heads may be exported under permit.

Minnesota: All protected game.

Exceptions: Nonresident licensee may ship home in open season under his license coupons 1 deer and 25 birds lawfully taken by himself. Domesticated big game may be exported under permit, and also deer and moose hides for tanning and moose heads for mounting.

Mississippi: All protected game.

Missouri: All protected game.

Exceptions: Game may be exported under resident or nonresident license if carried openly as baggage or express or in owner's possession and accompanied by him. Export for scientific or propagating purposes allowed under permit. Deer or elk raised in captivity may be shipped at any time.

Montana: All protected game.

Exception: Game lawfully killed may be exported in open season if accompanied by owner and resident's shipping permit from State game and fish warden or nonresident's hunting license; total shipment under one license not to exceed season's bag limit; packages to be labeled to show contents.

Nebraska: All protected game.

Exception: Nonresident may ship 50 birds out of State under hunting license, but must give common carrier invoice of number and kind of birds, must have details of shipment marked on license, and must accompany the shipment.

Nevada: All protected game.

New Hampshire:[1] Deer (except heads for mounting), elk, moose, caribou, quail, partridge, ruffed grouse, pheasant, woodcock, Wilson snipe, dove, plover, yellowlegs, sandpiper, rail, duck (except sheldrake), and all "beach" birds.

Exceptions: Deer may be exported by resident if accompanied to office of carrier by owner, shipped open to view, properly tagged, and labeled with name of actual owner. Nonresident may export, under his hunting license, 2 deer and 12 birds, carried open to view, on notice of number and kind to the commissioner who issued the license.

New Jersey: Hare, rabbit, squirrel, and all protected game birds.

Exceptions: Nonresident licensee may carry openly from the State 10 rabbits, 50 reed birds, 50 rail, and 15 other game birds a day. Live deer may be exported for propagation on payment of additional fee of $5 for each animal; English, ringneck or other pheasants, mallard and black ducks, and deer raised in inclosed preserves may be exported for sale if properly tagged.

New Mexico: Export for market of all game taken in the State, except plover, curlew, snipe, mallard and black duck.

Exception: The State warden is authorized to issue transportation permits at $1 each ($2 in case of deer), and also to permit export of game or birds for scientific or propagating purposes.

New York: Game or birds taken in the State.

Exceptions: Nonresident may export one deer and one day's bag limit of other game under permit. Foreign game or game raised in licensed preserves may be exported unaccompanied by the owner in any quantity when duly marked and tagged. Game for propagation and heads and skins of quadrupeds and game birds legally captured may be exported.

North Carolina:[2] Quail, partridge, pheasant, grouse, wild turkey, snipe, shore or beach bird, woodcock taken in State.

Exception: Nonresident may take out of State under his hunting license 50 quail (partridges), 12 grouse, 2 turkeys, and 50 beach birds or snipe in a season. Export permitted under permit of Audubon Society of ruffed grouse, wild turkey, woodcock, snipe, and other shore birds, for propagation.

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[1] Blue Mountain Forest Association permitted to ship deer, elk, and moose killed in its preserve.

[2] Export is also prohibited by the following local laws: *Deer*, Cherokee, Craven, Hyde (Currituck Township); *squirrel*, Craven; *quail*, Alexander (for sale—except 50 at one time by nonresident licensee), Catawba, Cherokee, Clay, Cleveland (3 years), Craven, Harnett, Henderson, Iredell, Jackson, Montgomery, Rutherford, Stanly (for sale—except by owner or lessee of land on which killed), Surry (for sale), Swain (live) Union (for sale), Yadkin (for sale); *wildfowl*, Craven (from State), Brunswick (Mar. 10–Nov. 10), Dare (Mar. 10–Nov. 10), New Hanover (Mar. 10–Nov. 10), Stanly (for sale—except by owner or lessee of land on which killed); *other game birds*, Cherokee (pheasant, dove, woodcock, robin, snipe), Craven (wild turkey, dove, woodcock), Montgomery (pheasant, wild turkey, dove), Stanly (all game birds), Tyrrell (woodcock, snipe—unless killed Nov. 1–Feb. 1), Union (dove, lark—for sale),

North Dakota: All protected game, except golden plover and woodcock.

Exceptions: Nonresident licensee may carry with him from State prairie chickens and doves, not exceeding 20 in all, and plover, snipe, ducks, and geese, not exceeding 50 in all, open to view, labeled with his name and address and number of his license. Domesticated game may be exported under written permission of board of control.

Ohio: Squirrel, quail, ruffed grouse or pheasant, introduced pheasant, dove, woodcock, plover, snipe, shore birds, rail, coot (mud hen), duck, goose, swan taken in the State.

Exception: Nonresident may take with him from State under his hunting license 25 pieces of game.

Oklahoma: All protected game.

Exception: Nonresident licensee may carry to his home two days' bag limit of game birds.

Oregon: All protected game.

Exceptions: Game birds raised in captivity for breeding purposes and pinioned may be shipped under tag. Game for propagation or scientific purposes may be exported under permit.

Pennsylvania: All protected game taken in the State.

Exceptions: Nonresident licensee may take with him from the State one day's bag labeled with his name and address and number of his license. Elk raised in captivity may be exported under regulations of commission. Live English, Mongolian, and Chinese pheasants raised in captivity may be exported.

Rhode Island: Quail, ruffed grouse, woodcock, plover, curlew, yellowlegs, snipe, sandpiper, shore, marsh and beach birds.

Exception: Nonresident may take with him from the State under his hunting license, open to view, 10 wildfowl or birds the export of which is otherwise prohibited by law.

South Carolina: All game birds or animals taken in the State.

Exception: Licensee may carry openly 2 deer, 50 partridges, 12 ruffed grouse, 4 wild turkeys, 50 beach birds, 50 ducks and geese in a season.

South Dakota: All protected game.

Exceptions: Two deer. A certificate—good for five days—that such game was lawfully killed must be obtained from a justice of the peace and given to the carrier. Any resident or nonresident may carry out of the State any game bird legally in possession. Game or game birds raised in captivity may be exported under written permission of State game warden.

Tennessee: All protected game.

Exception: Nonresident may take with him from the State 50 ducks or 30 pieces of other game, but must present to some officer or employee of common carrier his hunting license and sworn statement that his game will not be sold.

Texas: All wild animals, wild birds, and wild fowl found in the State.

Exception: Nonresident licensee may take with him from the State 3 male deer, 75 ducks (if killed in three consecutive days by himself), and one day's bag limit of other birds, under affidavit that his game will not be sold.

Utah: All protected game.

Exception: Nonresident licensee may take one day's bag out of State under permit.

Vermont: Deer, gray squirrel, quail, ruffed grouse or partridge, plover, English snipe, woodcock, duck, goose.

Exceptions: Nonresident licensee may export 1 deer and one day's bag of game birds under license, but must accompany shipment. Resident may export, open to view, the season limit of game or game birds under his license by having the license marked with shipping point, destination, and number of each kind of game. Also game raised in private preserves may be exported when duly marked and tagged.

Virginia: All protected game except waterfowl legally killed.

Exceptions: During open season nonresident may, under his hunting license, take with him out of the State, or as baggage on the same conveyance, 1 deer, 50 quail or partridges, 10 pheasants or grouse, 3 wild turkeys, and 25 of each, or 100 in all, of plover, snipe, sandpipers, willets, tatlers, and curlew, if killed or captured by himself and shipped open to view and plainly labeled with his name and address. Any citizen of State may ship from the State, as a gift and not for sale (which fact must be stated on shipping tag), 1 deer, 18 quail or partridges, 6 pheasants, 3 wild turkeys, and if open to view and plainly labeled with names and addresses of donor and donee, and number of each kind of bird so shipped.

Washington: All protected game.

Exceptions: Nonresident may export one season's limit of big game and one day's bag limit of birds under his hunting license, if accompanied by affidavit that the game was killed by him and is not for sale. Export of game animals and birds raised in captivity permitted.

West Virginia: All protected game.

Wisconsin: All protected game, except rabbit, squirrel, and coot (mud hen).

Exceptions: During open season nonresident may take out of State under his hunting license, in personal possession or as baggage or express, accompanying same to State line, 1 deer and not more than 30 game animals and birds of all kinds, provided packages are plainly marked so as to show the names and addresses of shipper and consignee and number of each kind of game, and, in case of deer, have proper coupons attached. Park boards allowed to ship, under permit of State game warden, live animals and game birds for park purposes. Shipment allowed of domesticated deer, moose, elk, and caribou and game birds properly tagged, under permit of State game warden.

Wyoming: All protected game.

Exceptions: Smithsonian Institution or other well-known scientific institutions may export any game animals or birds under permit of State game commission.

Export of 1 hide, 1 scalp, 1 head, 1 pair of tusks, 1 skin, 1 mounted head, 1 mounted specimen, of any big game except moose permitted upon affidavit that they were taken from animals lawfully killed, the payment of 25 cents to the justice of the peace of precinct where affiant lives, and attachment of the tag issued by him; a nonresident (or resident, when necessary to cross territory of another State to reach his home) may export under his hunting license 20 dead game birds and the carcass, head, antlers, scalp, skin, and teeth of any animal lawfully killed; exchange of game animals and birds for others for liberation in Wyoming allowed under permit of the State game commission; big game, except moose, captured and held for propagation may be exported after five years.

Alberta: All protected game.

Exceptions: Minister of agriculture on receipt of a $5 fee may grant a permit to export for propagation or scientific purposes one pair of each species of big game and game birds. The lieutenant governor in council may grant permits for a greater number. The minister of agriculture may also issue permits for export of game for other purposes at the rate of $5 for each head of big game and $1 per dozen for game birds. The holder of a general nonresident license may take with him out of the Province as trophies, heads, skins, and hoofs of big game legally killed by him. Any person may export mounted or branded heads at a fee of $1 for each head.

British Columbia: All protected game, except bears.

Exceptions: Heads, horns, and skins of big game lawfully killed by the shipper may be shipped under his hunting license and written permission of minister charged with enforcement of act. Any animal or bird, dead or alive, may be exported for scientific, zoological, or Government purposes under permit of provincial secretary. Live game birds or animals held in captivity under written permission of provincial game warden may be exported.

Manitoba: All protected game.

Exceptions: Minister of agriculture and immigration may direct chief game guardian to export not more than 12 animals or birds for propagation and may issue permit to export heads and skins of big game animals, and any game birds, except grouse, prairie chicken, and partridge, but not more than 100 geese and swans or 50 ducks, and these only under nonresident license. (No export of ducks permitted before October 1.) The following export fees are charged: Deer or deer head, $2 each; head of elk, moose, or caribou, or carcass, $5 each; any hide, 10 cents. No export fee required of nonresident licensee.

New Brunswick:[1] All protected game.

Exception: Surveyor general may issue special license to export game alive or dead.

Newfoundland: Caribou (antlers, heads, or skins), or partridge, willow or other grouse for sale.

Exceptions: Minister of marine and fisheries may issue licenses to export caribou for breeding or scientific purposes. Nonresident may export 3 stag caribou under hunting license and export permit (fee, 50 cents); resident may export antlers, head, or skin of caribou under export permit; but not, in either case, for sale.

Nova Scotia: All protected game.

Exceptions: Holder of general license may ship out of Province 1 moose lawfully shot by himself. Mounted heads and dressed skins and live mammals or birds for propagation or scientific purposes may be exported under permit from provincial secretary.

Ontario: All wild game animals and birds.

Exceptions: One deer, 1 bull moose, 1 bull caribou, and 100 ducks may be exported under nonresident hunting license if shipping coupon and, if required, affidavit of lawful killing be attached and contents of packages be open to view. Lawfully imported game and deer, moose, elk, or caribou held by private ownership may be exported.

Prince Edward Island: All game except geese and brant.

Exception: Nonresident licensee may carry out of Province 12 birds killed by himself.

Quebec: Native deer, moose, caribou, or parts thereof, except under permit from Minister of colonization, mines, and fisheries (fee not to exceed $5), or under tags attached to nonresident licenses, and not later than 15 days after close of season.

Saskatchewan: All protected game.

Exceptions: Minister of agriculture may grant permits to export for propagation for public parks and zoological gardens or scientific purposes 1 pair of each species of big game and game birds upon payment of $5, or a specified number on application of another Province or State. Minister may issue permits to export big game (fee $5 per head), ducks, or geese (fee $1 per dozen, limit 5 dozen per season.)

Yukon: Protected game can be exported by a nonresident only under a hunting license and a shipping permit issued by the commissioner of the Territory, or a game guardian. Permits export of one head of each of the following kinds of big game: Moose, caribou, sheep, and goat.

Canada also has a general law prohibiting export of deer (except those raised on private preserves), wild turkeys, quail, partridges, prairie fowl, and woodcock, but permitting each nonresident to ex-

[1] Except in the case of partridge the prohibition applies only to common carriers.

port two deer [1] in a year at certain ports within 15 days after the close of the open season, under permit of the collector of customs of the port from which export is made. The ports of export are: Halifax and Yarmouth, Nova Scotia; Macadam Junction, New Brunswick; Quebec and Montreal, Quebec; Ottawa, Kingston, Niagara Falls, Fort Erie, Windsor, Sault Ste. Marie, and Port Arthur, Ontario; and such others as the minister of customs may designate.

Those who visit Canada to hunt, camp, etc., must deposit with the customs officer at the port of entry an amount equal to the duty (30 per cent of appraised value) on their guns, canoes, tents, cooking utensils, and kodaks. If these articles are taken out within six months at the same port, the deposit will be returned. But members of shooting or fishing clubs that own preserves in Canada and have filed a guaranty with the Canadian commissioner of customs may present club membership certificates in lieu of making the deposit. They must, however, pay duty on all ammunition and provisions.

SALE.

Legislation restricting the sale of game is passing through a transition stage. Some States prohibit the sale of game throughout the year, others only in close season, and between these extremes may be found all gradations and exceptions, such as restrictions prohibiting sale of game outside the State or for export, and exemptions allowing sale for a few days in the close season. The difficulty of tabulating such regulations is increased by the fact that in addition to the special sale laws, close seasons and provisions regarding possession must be taken into consideration. In consulting the following summary, therefore, it will be necessary to bear in mind three different classes of restrictions: "Sale in close season," "Sale in open season," and "Sale prohibited all the year."

SALE IN CLOSE SEASON.

In general, the sale of game is prohibited during the close season but a brief additional open period is sometimes provided in order to permit dealers to close out stock on hand at the end of the hunting season. In Louisiana an extension of three days is allowed. In Colorado, Illinois, Tennessee, and British Columbia the sale season includes the open season and the following five days for all or certain kinds of game. An extension of 10 days for sale is added to the open season in New Brunswick; 15 days in Alaska, New Jersey, and Quebec; 30 days in Pennsylvania; 60 days in Yukon; 3 months (for geese and brant) in New Brunswick; and until the following 1st of January in Ontario.

[1] Except from Ontario (see above).

SALE IN OPEN SEASON.

In order to counteract a tendency on the part of market hunters to anticipate the opening of the season, the sale of certain game is sometimes prohibited at the beginning of the open season, as during the first two days in Illinois, the first three in Nova Scotia and Quebec, and the first month in British Columbia.

SALE PROHIBITED ALL THE YEAR.

Forty-seven States[1] and most of the Provinces of Canada now prohibit sale of all or certain kinds of game at all seasons. In Alabama, Arizona, Arkansas, Colorado, Florida, Georgia, Idaho, Iowa, Kansas, Mississippi, Missouri, Montana, Nebraska, Nevada, Oklahoma, Oregon, South Carolina, Texas, Washington, West Virginia, and Wyoming, the sale, and in Delaware the resale, of all protected game is prohibited; in Michigan and Ohio, of all game except rabbits; in New York and New Jersey of all game except rabbits and that raised in licensed preserves and a few imported species; in Minnesota, of all game except that raised in captivity; in Wisconsin, of all game except rabbits, squirrels, coots, and rails; in California, of all game except ducks; in Utah and Manitoba, of all big game and upland game. In a few instances prohibitions against the sale of certain game are so general as to afford protection over a considerable area in adjoining States. Thus, ruffed grouse can not be sold in any State or Province along the Canadian border except Quebec. Practically every State in which prairie chickens occur now prohibits their sale or export.

The following statement shows the kinds of game the sale of which is prohibited throughout the year. The sale of all other game is so generally prohibited during the close season as to render a detailed enumeration unnecessary, but when an extension of a few days is added to the open season or a special season is provided for either possession or sale, attention is called to this exemption under the heading "Permitted."

Sale of game prohibited throughout the year.

Alabama: All protected game.

Alaska: Heads, hides, and skins of all protected game. Deer until August 15, 1914.

Permitted: Carcasses of all game may be sold during the open season and 15 days thereafter.

Arizona: All protected game.

Arkansas: All "game, wild fowl, or birds whatsoever," except deer raised in captivity, bears, rabbits, opossums, raccoons, and squirrels.[2]

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[1] Omitting Alaska, which prohibits sale only of heads, skins, and trophies and deer in southeastern Alaska until Aug. 15, 1914; District of Columbia, which prohibits sale only in close season; North Carolina, which prohibits sale in only a few counties.

[2] Squirrels killed in Ouachita and Union Counties can not be sold, and no squirrels can be sold in Craighead, Dallas, and Lafayette Counties. Wildfowl may be sold in the Chickasawba district in Mississippi County.

California: Deer meat and hides of female deer, or those from which evidence of sex has been removed, all other protected game, except cottontail rabbit, duck, and black brant.

Permitted: Game may be sold under license. Pheasants reared in captivity or imported from foreign country may be sold at any time under permit.

Colorado: All game taken in the State.

Permitted: Domestic game may be sold by hotels, restaurants, etc., during the open season and five days thereafter, or during the limits of a storage permit. Imported game (under license) and game taken from licensed private parks and lakes may be sold at any time if accompanied by an invoice.

Connecticut: Quail, ruffed grouse, Hungarian partridge, woodcock.

Delaware: All protected game, except that a resident lawfully taking game may sell plover, snipe, and ducks anywhere and other game in his own county; restaurants buying from such persons may serve game in open season.

Florida: All protected game.

Georgia: All protected game, except migratory ducks.

Idaho: All protected game.

Illinois: All protected game, except dove, coot, rail.

Permitted: Deer bred in captivity may be sold October 1 to February 1; cock pheasants may be sold by breeders (under permit) November 1 to February 1; doves may be sold from the third day of the open season to the fifth day of the close season; and legally killed game imported from other States from October 1 to February 1.

Indiana: Quail.

Iowa: All protected game.

Kansas: All protected game.

Permitted: Game reared in captivity may be sold under permit.

Kentucky: Quail, partridge, grouse, pheasant, wild turkey, killed in the State.

Louisiana: All protected game, except snipe, rail coots, poule d'eau, ducks, geese, and brant, which may be sold during open season and three days thereafter, but not later than March 1.

Permitted: Game reared in captivity may be sold during the open season.

Maine: Deer or moose for export. All protected game birds for any purpose.

Permitted: Deer may be sold by local dealers under license.

Maryland:

Allegany—Deer, quail, grouse, English pheasant, wild turkey, dove, woodcock.

Anne Arundel—All game except squirrel, rabbit, and raccoon.

Baltimore—Rabbit, squirrel, quail, ruffed grouse, dove, pheasant, woodcock, for export.

Calvert—Rabbit, quail, woodcock, for export for sale.

Cecil—Squirrel, quail, grouse, woodcock, plover.

Dorchester—Rabbit, squirrel, quail, partridge, dove, woodcock, wood duck, for export.

Frederick—Squirrel, partridge, pheasant, woodcock, taken in county.

Garrett—Rabbit, partridge, quail, pheasant, wild turkey, woodcock, for export.

Montgomery—Rabbit, quail, partridge, woodcock, for export.

Somerset—Rabbit, quail or partridge, woodcock, dead or alive, for any other purpose than as food within the county or for propagation; or any game for export.

Washington—Deer, squirrel, rabbit, partridge, pheasant, wild turkey, dove, woodcock.

Wicomico—Quail or partridge for export (from Wicomico and Worcester Counties considered as one territory).

Worcester—Rabbit, quail, woodcock (except to consumer).

Permitted: Baltimore City—Ruffed grouse may be sold October 1–December 25.

Massachusetts: Deer and quail taken in the State, gray squirrel, ruffed grouse, prairie chicken, sharp-tailed grouse, pheasant, Hungarian partridge, woodcock, piping plover, and killdeer plover.

Permitted: Dealers or persons in the cold-storage business may sell imported quail lawfully obtained during November and December, and may sell at any time hares or rabbits lawfully secured. Live quail for propagation may be sold under permit. Quail and Hungarian partridges raised in captivity under written permit may be sold for propagation. Deer and pheasants raised in captivity may be sold for any purpose.

Michigan: All protected game, except rabbits.

Permitted: Game raised in captivity may be sold alive within State and, under $1 permit, alive or dead without the State.

Minnesota: All protected game.

Permitted: Game animals (under permit) and birds (under tag) raised in captivity may be sold at any time.

Mississippi: All protected game.

Missouri: All protected game.

Permitted: Deer or elk reared in captivity may be sold under regulations of commissioner.

Montana: All protected game.

Permitted: Merchant, hotel, or restaurant keeper may sell game not killed in the State.

Nebraska: All protected game.

Nevada: All protected game.

New Hampshire: Deer (except 2), gray squirrel (to Oct. 1, 1919), ruffed grouse or partridge, woodcock,

New Jersey: Deer, squirrel, or game birds except waterfowl, or any game belonging to a family, any species of which is native to and protected by the State.

Permitted: Rabbits and waterfowl; certain imported game; and also deer, pheasants, black and mallard ducks raised in preserves or coming from another State may be sold at all times of the year if properly tagged.

New Mexico: All protected game taken in the State except plover, curlew, and snipe.

Permitted: Sale of game raised in licensed preserves.

New York: All game belonging to a family any species or subspecies of which is native to and protected by the State.

Permitted: Varying hares and rabbits during open season, and unplucked carcasses of pheasants, Scotch grouse, European black game, European black plover, red-legged partridge, and Egyptian quail, and carcasses of European red deer, fallow deer, roebuck, and reindeer imported from without the United States may be sold under license at any time.

American elk, white-tailed deer, European red deer, fallow deer, roebuck, pheasants, mallard, and black ducks raised in captivity under license, may be killed and sold under license at any time; breeder of pheasants may, under license, kill by shooting his surplus cock pheasants during February.

North Carolina: Local restrictions in Alexander, Brunswick, Cabarrus, Cherokee, Cleveland, Craven, Harnett, Henderson, Iredell, Mecklenburg, Moore, New Hanover, Pender, Randolph, Richmond, Rutherford, Scotland, Stanly, Transylvania, and Union Counties.

North Dakota: All protected game, except woodcock and plover.

Permitted: Hides of big game lawfully taken may be sold at any time. Domesticated game may be sold on written permission of the game board of control.

Ohio: All protected game, except rabbits.

Oklahoma: All protected game.

Permitted: Domesticated game animals and birds, and heads, hides, and horns of big game lawfully killed may be sold.

Oregon: All protected game.

Permitted: Game birds and animals imported from without the United States may be sold Sept. 1–Mar. 1, and game or animals raised in captivity under permit at any time, upon being properly tagged by commissioner or deputy.

Pennsylvania: Wild deer or elk taken in State; quail, ruffed grouse (pheasant), wild turkey, and woodcock (wherever taken).

Permitted: Squirrel, rabbit or hare, bear, reedbird, black-breasted and golden plover, Wilson or jacksnipe, yellow legs, coot or mud hen, rail, taken in State, may be sold during open season and 30 days thereafter; waterfowl may be sold Sept. 1–Jan. 1. Game or birds used for propagating purposes may be sold at any time under authority of game commissioners.

Rhode Island: Quail, ruffed grouse, pheasant, woodcock, plover, yellow legs, snipe, curlew, sandpiper, shore, marsh, and beach birds.

South Carolina: All protected game.

South Dakota: All protected game, except dove, golden and upland plover, and woodcock.

Permitted: Hides, heads, or horns of big game lawfully killed may be sold at any time. Game or game birds raised in captivity may be sold under written permission of State game warden.

Tennessee: Quail, robin. In Dyer County also wild turkey.

Permitted: All game except quail and robin may be sold in the State during the open season and five days thereafter.

Texas: All game animals, hides and horns, wild birds, and wild fowl found in the State.

Utah: Deer, elk, antelope, sheep, quail, partridge, grouse, prairie chicken, sage hen, pheasant, Mongolian, Chinese, and English pheasant, dove.

Permitted: 25 in all of shore birds and waterfowl may be sold in a day to private parties.

Vermont: All protected game birds or species belonging to any family native to the State.

Permitted: Deer may be sold during the open season and for a "reasonable time thereafter," and hares and rabbits during the open season. Game from private preserves may be sold under tag in accordance with regulations of the commissioner.

Virginia: Quail or partridge, grouse or pheasant, robin, woodcock.

Clarke County.—Rabbit, squirrel, wild turkey (outside of county).

Frederick, Shenandoah Counties.—Wild turkey (by nonresidents of Virginia).

Washington: All protected game.

Permitted: Hides and horns of big game legally killed, and propagated game animals and birds may be sold for propagation purposes at any time.

West Virginia: All protected game, except reedbird and rail.

Wisconsin: All protected game, except rabbit, squirrel, coot (mud hen), and rail.

Permitted: Domesticated deer, moose, elk, caribou, and game birds may be sold under permit of State fish and game warden.

Wyoming: All protected game.

Permitted: Sale of 1 live game animal, 1 skin, 1 mounted head, 1 mounted specimen, 1 pair of tusks, 1 hide, 1 scalp, and 1 head of any big game, except moose, on affidavit that they were lawfully captured or were taken from animals lawfully killed and payment of 25-cent fee to the justice of the peace of precinct where affiant lives and attachment of tag issued by him. Sale of the natural increase of any big game, except moose, captured and held for propagation.

Alberta: Grouse, partridge, pheasant, prairie chicken, ptarmigan; other game birds Mar. 1-Sept. 20.

Permitted: The flesh of big game and game birds may be sold under $10 license. Heads of big game before being sold must be stamped by minister of agriculture at fees of $5 for elk, caribou, moose, and sheep, and $2 for deer, antelope, and goat.

British Columbia: Elk, quail, grouse, ptarmigan, prairie chicken, English partridge, pheasant, swan, female and young of deer, moose, caribou, or sheep, heads of moose, caribou, and sheep.

Permitted: Male deer may be sold September 1–November 16; male moose, caribou, sheep, goats, and hares after October 1; snipe, ducks, and geese, October 1–December 1; and plover during the open season and five days thereafter. Lieutenant governor in council may alter or extend sale seasons.

Manitoba: Deer, elk, moose, caribou, antelope (except heads and hides), quail, grouse, pheasant, partridge, prairie chicken, woodcock, plover, snipe, sandpiper. Ducks can not be sold before October 1.

Permitted: Possession of grouse, prairie chickens, and partridges allowed for forty-five days, and ducks for three months, after close of hunting season. Deer for private use may be possessed at any time on proof of legal killing.

New Brunswick: Partridge until September 15, 1915.

Permitted: Geese and brant during open season and until March 1, and other game during open season and (under license) ten days thereafter. Keepers of hotels, inns, boarding houses, or restaurants may serve game during open season and fifteen days thereafter. Surveyor general may issue $1 licenses to dealers permitting sale by each of 3 deer and heads of same to taxidermists, and licenses to deal in hides or skins of game animals with fees of $25 to nonresidents or aliens and $2 to residents.

Newfoundland: Capercailzie, black game.

Permitted: Caribou may be sold from August 1 to January 1.

Nova Scotia: Deer to 1915, caribou, pheasant, blackcock, capercailzie, Canada grouse (spruce partridge), chukar partridge.

Permitted: Moose may be sold from September 17 to December 1. Rabbit, December 1 to March 1. Any game bird other than those above mentioned during the open season with the exception of the first three days.

Ontario: Quail, partridge, woodcock, snipe, to September 15, 1914.

Permitted: All other native game may be sold during the open season[1] by the person killing it and by dealers during open season and until the following January 1 under license. Imported game may be sold under special regulations and licenses.

Quebec: [2]

Permitted: All game lawfully taken may be sold from the third day of the open season to the fifteenth day of the close season. Hotels, restaurants, and clubs may serve, under license, all game lawfully taken, except birch or swamp partridge. Live animals, and skins and heads of animals lawfully taken may be sold.

Saskatchewan: Sheep, goat, or prairie chicken, grouse, pheasant, ptarmigan, or other member of the Gallinæ.

Yukon:

Permitted: Deer, elk, moose, caribou, bison, musk oxen, sheep, and goats may be sold during the open season and sixty days thereafter.

LIMITS.

Laws limiting the amount of game which can be killed in a day or a season are now in force throughout the United States, except in Kentucky, Rhode Island, Virginia, and the District of Columbia, and in all the Canadian Provinces, except Prince Edward Island. These measures are of comparatively recent origin. One of the first statutes of the kind was that passed in Iowa in 1878 (ch. 156, sec. 3) limiting the killing or possession of prairie chickens, snipe, woodcock, quail, and ruffed grouse to 25 in a day.[3] Maine, in 1883 (ch. 185, sec. 1), limited the number of big game which an individual might kill in a season to 1 moose, 2 caribou, and 3 deer, and New York, in 1886 (ch. 194, sec. 1), likewise limited the number of deer to 3. In spite of the objection often urged against such statutes—that they are impossible of enforcement and easily evaded—experience has shown them to

[1] Seasons depend on regulations of game commission.

[2] Lieutenant governor in council may prohibit sale of any game for three years or less or prolong any existing period of prohibition for three years or less.

[3] This statute was, however, preceded by one enacted in 1874 limiting the shipment of game birds to a dozen a day, provided the birds were not shipped for sale (ch. 69, sec. 1).

constitute one of the most effective features of modern game legislation. They have been tested in the courts and upheld by the supreme courts of several States, notably those of Maine and Wisconsin.[1]

When restrictions on limits are extended to possession and shipment as well as killing, and the total amount of game allowed a party made less than the quantity allowed the individual members of the party, little difficulty is experienced in enforcing the statute. Moreover, among law-abiding sportsmen the incentive to make large bags is removed when the act is declared illegal.

In recent years bag limits have been materially reduced, and only a few States now allow more than 2 deer a season or 1 head of other big game, while the usual limits per day in the case of birds are 10 grouse or woodcock, 15 quail, and 25 waterfowl. In Canada, where the country is not so closely settled, bag limits on most game are fewer and more liberal than in the United States.

Limits fixed by law for the capture of game.

Alabama: One deer, 2 turkey gobblers, 25 of each other kind of birds a day.

Alaska: Six deer, 2 moose, 3 caribou, 3 sheep, and 3 brown bears a season; 25 grouse, ptarmigan, shore birds or waterfowl a day.

Arizona: Two deer, 3 turkeys a season, 25 each of quail or ducks, 35 doves or white wings a day.

Arkansas: No limits, except in the following counties: Deer, Bradley 3, Dallas 3, Desha 4, Phillips 4 (or 1 for each member of party), Chicot 5, a season; quail, Bradley and Dallas 300 a season or 25 a day for each member of party. Monroe, 3 deer, 2 bears, 100 quail, 5 wild turkeys, and 100 ducks a season; party limits, 1 deer, 1 bear, 10 quail, 1 wild turkey, 15 ducks for each member.

California: Two deer, 12 tree squirrels a season; 15 cotton-tail or bush rabbits, 4 grouse, 4 sage hens, 10 mountain quail, 20 each of desert or valley quail, doves, plover, curlew, snipe, or other shore birds, and ibises, and 25 ducks and black sea brant a day; 50 ducks or black sea brant per week.

Colorado: Twenty game birds a day, 30 in possession at one time. Persons under 12 years of age limited to half this number of birds.

Connecticut: Five each of quail and ruffed grouse a day, 36 a year; 35 rail, 50 each of plover, snipe, shore birds a day.

Delaware: Six animals, 50 rail, 20 ducks, 12 other birds or fowl, except plover, snipe and reedbirds, a day.

District of Columbia: No limits.

Florida: Three deer, 5 turkeys, and 500 other game birds a year; 1 deer, 2 turkeys, 20 quail, and 25 each of other species a day.

Georgia: Three deer, 3 turkeys a season; 40 doves or snipe, and 25 each of any other species of game birds a day.

Idaho: Two deer, 1 elk, 1 ibex, 1 goat, 1 sheep a season; 18 quail, 12 each of partridges, sage hens, grouse pheasants, 24 doves, plover, snipe, ducks, 4 geese, 1 swan a day; but not more than 24 of all kinds in possession at one time.

Illinois: Fifteen squirrels, 12 quail, 3 prairie chickens, 15 doves, 15 shore birds, 15 coots, 15 rail, 15 ducks, 10 geese, 10 brant, 15 other waterfowl a day.

Indiana: Fifteen quail, 15 ducks or other waterfowl a day; 45 birds in possession as result of 3 or more days' consecutive hunting.

Iowa: Twenty-five each of all animals, birds, and game a day; 50 ducks in possession at one time.

Kansas: Twenty each of dove, plover, duck, 12 snipe and 6 each of geese and brant a day.

Kentucky: No limits.

Louisiana: Two deer a day or in possession at one time, 5 a season; 10 squirrels, 1 turkey gobbler, 25 doves, ducks, poule d'eau, or chorooks, 50 snipe, 15 of any other game birds a day. Market hunters, 50 ducks or poule d'eau a day.

Maine: One moose, 2 deer a season (except in Androscoggin, Cumberland, Knox, Kennebec, Lincoln, Sagadahoc, Waldo, and York Counties, limit 1, and in lumber camps, limit 6); 5 each of ruffed grouse and plover, and 10 each of woodcock, snipe, and ducks, and 50 sandpipers a day.

Maryland: One deer a season; 12 rabbits, 12 squirrels, 15 quail (partridges), 6 ruffed grouse (pheasants), 3 English pheasants, 2 wild turkeys, 25 doves, 12 woodcock, 12 jacksnipe a day; 50 rail (ortolan) per tide.

Exceptions.—Baltimore, per day: 6 rabbits, 1 jack rabbit, 8 squirrels, 10 quail (partridges), 2 ruffed grouse (pheasants), 1 English pheasant, 1 ring-neck pheasant, 1 wild turkey, 10 doves, 8 woodcock, 12 jacksnipe; per tide: 28 rail. Calvert, per day: 6 rabbits, 12 partridges. Cecil, per day: 5 rabbits, 6 squirrels, 12 quail (partridges), 4 ruffed grouse (pheasants), 12 woodcock, 15 snipe, 50 rail, 50 blackbirds, 20 Bartramian sandpipers (grass plover), 20 marsh plover, and 25 each of teal, wood, mallard, black, sprigtail, and crow-bill ducks. Patuxent River, per day: 75 rail (ortolan), 75 reedbirds.

[1] See Allen *v.* Leighton, 32 Atl., 877 (Maine, 1895); State *v.* Nergaard, 102 N. W., 899 (Wisconsin, 1905).

Massachusetts: One deer; 15 gray squirrels, 15 ruffed grouse, 20 woodcock, 20 quail a season; 5 gray squirrels, 3 ruffed grouse, 4 woodcock, 4 quail, 15 black ducks a day.

Michigan: Two deer, 50 each of partridges, spruce hens, woodcock, plover, 50 in all of snipe and other shore birds a season; 6 in all of partridges and spruce hens a day, 15 in possession; 6 woodcock, 6 plover a day, 20 each in possession; 10 in all of snipe and other shore birds a day, 20 in possession; 25 in all of ducks, geese, and brant a day or in possession at one time.

Minnesota: One deer, 1 moose a season; 15 birds a day; 45 quail, partridges, ruffed grouse, pheasants, prairie chickens, white-breasted or sharp-tailed grouse, doves, plover, woodcock combined; 50 snipe, duck, goose, brant, any aquatic fowl combined, in possession at a time.

Mississippi: One deer a day, 5 a season; 20 each of quail, wild turkeys, robins, cedarbirds, plover, tatlers, chorooks, grosbecs, coots, poule d'eau, rails, ducks, geese, brant, swans a day.

Missouri: One deer, 2 turkeys, 10 of any other species a day; or 2 deer, 4 turkeys, 15 of any other species in possession at a time.

Montana: Three deer (one doe and 2 bucks, or 3 bucks), 1 elk, 1 goat, 1 sheep (male) a season; 5 each of grouse, partridges, prairie chickens, fool hens, pheasants, sage hens, and 20 ducks a day.

Nebraska: Ten squirrels, 10 quail, 10 prairie chickens or grouse, 10 wild geese or brant, and 25 game birds of any other variety a day; 20 squirrels, 10 prairie chickens or grouse, 10 wild geese or brant, or 50 other game birds in possession at one time.

Nevada: Two deer a season; 15 mountain quail, 15 valley quail, 10 sage hens, 6 grouse, 5 plover, and 15 snipe, 20 ducks, 10 geese, 3 swans a day.

New Hampshire: Two deer a season in Coos, Carroll, and Grafton Counties, 1 in rest of State.

New Jersey: One deer a season; 10 rabbits, 10 quail, 3 ruffed grouse, 3 English or ringneck pheasants, 3 Hungarian partridges, 10 woodcock, 30 marsh hens, 20 ducks, 10 each of geese and brant a day or in possession. (Not applicable to dealer in game, hotel keeper, etc., during open season at place of business.)

New Mexico: One deer a season; 4 wild turkeys, 6 grouse, 20 ducks, 30 other birds a day or in possession at one time.

New York: Two deer, 20 woodcock, 20 grouse, 3 male imported pheasants a season; 6 varying hares or rabbits, 5 squirrels, 4 woodcock, 4 grouse, 25 waterfowl (limit for one boat or battery, 40), 15 rails, coots, mudhens or gallinules (limit for one boat 20), 15 shore birds (limit for one boat 25) a day. Long Island: 50 quail, 20 ruffed grouse, 36 male pheasants a season; 10 quail, 4 ruffed grouse, 6 male pheasants, and 6 cottontail or varying hares a day.

North Carolina: Brunswick, New Hanover, Pender, 15 marsh hens a day; Buncombe, 2 deer a season, 25 partridges, pheasants, wild turkeys, or doves a day; Cabarrus, Mecklenburg, Surry, 15 quail (partridges) a day; Cleveland, 10 quail (partridges) a day; Dare, 5 deer a season; Haywood, 1 buck a day, 2 a season; 2 pheasants, 2 wild turkeys, or 20 birds in all, a day; Henderson, Jackson, 2 bucks a season; Madison, 25 birds a day; Transylvania, 3 deer a season, 5 squirrels, 20 quail (partridges) a day.

North Dakota: Ten prairie chickens, grouse, cranes, combined a day, 20 in possession at one time; 25 plover, snipe, woodcock, ducks, geese, brant combined, 50 in possession at one time.

Ohio: Five squirrels, 12 each of plover, snipe, woodcock, shore birds, rail, geese, 25 ducks a day.

Oklahoma: One deer a season; 1 turkey (male) March 15–April 15, 3 turkeys, November 15–January 1; 25 quail, plover, curlew, snipe, other shore birds, or ducks a day, 150 a season; 15 prairie chickens a day, 100 a season; 15 doves a day, 150 a season; 10 geese or brant a day; 1 swan a season.

Oregon: Three deer a season; 5 silver gray squirrels and 10 quail in 7 consecutive days; 5 sage hens a day, 10 in 7 consecutive days in district 2; 5 ruffed grouse, pheasants, sooty or blue grouse, and male Chinese pheasants a day, 10 in 7 consecutive days; 10 doves (State) and wild pigeons (district 1) a day 20 in 7 consecutive days; 30 shore birds, rail, coot, ducks, and geese in 7 consecutive days.

Pennsylvania: One deer a season; 6 squirrels, 10 rabbits or hares a day; 10 quail a day, 40 a week, 75 a season; 5 ruffed grouse a day, 20 a week, 50 a season; 10 each of English, Mongolian, or Chinese pheasants and woodcock a day, 20 a week, 50 a season; 5 Hungarian partridges a day, 20 a week, 30 a season; 1 wild turkey a day, 2 a season. Possession limited to season's limit.

Rhode Island: No limits.

South Carolina: Five deer a season; 25 quail (partridges), 2 wild turkeys, 25 doves, 12 woodcock, a day.

South Dakota: One deer a year; 20 waterfowl, 10 other birds a day; 25 partridges, ruffed grouse, prairie chickens, sharp-tailed (white-breasted) grouse, pheasants, woodcock, golden plover and upland plover, in aggregate in possession at one time; 50 snipe and waterfowl in aggregate in possession at one time.

Tennessee: Fifty ducks; 30 of all other birds in aggregate a day. Lauderdale County; 6 each of squirrels, ducks, and geese a day.

Texas: Three deer a season; 25 birds a day (3 wild turkeys December 1 to March 1).

Utah: One deer (residents only), 25 grouse a season; 15 quail, 8 sage hens, 6 grouse a day or in possession at one time; 12 geese a day, and 25 in all of snipe, ducks, geese a day.

Vermont: One deer and 25 ruffed grouse or woodcock a season; 5 each of rabbits or gray squirrels a day or in possession; 4 each of quail, ruffed grouse, partridges or woodcock a day; 10 in all of plover, English snipe, and other shore birds a day; 20 ducks a day.

Virginia: No limits.

Washington: Two deer (Okanogan County, 1 male), 1 sheep, 1 goat, 1 antelope, 1 caribou, a season; 5 in all of partridges, grouse, prairie chickens, and pheasants, 10 quail a day; 25 upland game birds a week; 20 in all of ducks, geese, and brant a week (week begins at midnight Wednesday night). If the bag of upland game birds includes quail, the limit is 10 a day.

West Virginia: Two deer a season; 12 quail a day, 96 a season; 6 ruffed grouse a day, 25 a season; 2 wild turkeys a day, 6 a season.

Wisconsin: One deer a year; 5 grouse, prairie chickens, woodcock, 10 partridges, 15 plover, snipe, coots, rail, rice hens, ducks, 10 geese or brant, a day; 20 of all kinds of birds in possession by resident in one day.

Wyoming: One deer, 2 elk (resident, 1 female and 1 additional elk under special license), 1 male sheep a season; 18 birds (of which not more than 6 may be grouse) a day, or in possession at one time.

Alberta: One deer, 1 elk, 1 moose, 1 caribou, 2 antelope, 2 sheep, 2 goats a season; 10 grouse, partridges, pheasants, prairie chickens, ptarmigan a day, or 100 a season.

British Columbia: Three deer, 1 elk, 2 moose (1 in county of Kootenay), 3 caribou, 3 goats, 2 sheep (1 in county of Kootenay), 250 ducks and snipe a season. (Nonresident licensee may kill 5 deer, caribou, and goats, but not more than 3 of any one species, and 3 moose, elk, and sheep, but not more than the bag limit of any one species.)

Manitoba: One in all of deer, elk, moose, caribou, and antelope a season; 20 in all of grouse, partridges, prairie chickens a day, 100 a season; 20 ducks a day in September, 50 ducks a day in October and November.

New Brunswick: Two deer, 1 moose, 1 caribou a season (lumber camp limited to 2 moose, 2 caribou a season); 10 partridges, 10 woodcock, 20 ducks a day.

Newfoundland: Three caribou (2 stags and one doe) a season.

Nova Scotia: One moose a season; 5 ruffed grouse, 10 woodcock a day.

Ontario: One deer, 1 moose, 1 caribou a season. Two or more persons hunting together under license may kill an average of 1 deer each; 10 partridges a day.

Prince Edward Island: No limits.

Quebec: Zone 1: Two deer, 1 moose, 2 caribou a season. Zone 2: Two deer, 1 moose, 4 caribou a season; 3 deer and 3 caribou additional may be taken by persons domiciled in Province under $5 permit.

Saskatchewan: Two in all of deer, elk, moose, caribou, and 2 antelope a season; 10 in all of grouse partridges, pheasants, prairie chickens, ptarmigan a day, or 100 a season; 50 waterfowl a day, 250 a season.

Yukon: Six caribou or deer, 2 moose, 2 elk, 2 sheep, 2 goats, 2 musk oxen a season.

LICENSES FOR HUNTING AND SHIPPING GAME.

In Arkansas nonresidents are not permitted to hunt, except on their own premises.[1] In all the States and throughout Canada licenses must be secured before nonresidents can hunt any or certain kinds of game (see fig. 2, p. 51). In 40 States[2] and 7 Canadian Provinces a like restriction is imposed on residents, but the fees are usually much smaller, and often are merely nominal (see fig. 3, p. 51).

A special kind of hunting license, often known as the "alien" license, is being generally adopted to restrict hunting by persons who are not citizens of the country, and is now in force in about half of the States.

In Maine,[3] Wyoming, New Brunswick (on wild lands), and Nova Scotia nonresidents are not permitted to hunt big game unless accompanied by qualified guides.

Landowners or taxpayers are not required to pay the usual fee in a number of States, and no license is required of those hunting in their own county in Michigan and Minnesota (birds), Texas or Nova Scotia. Special exemptions are made in favor of nonresident members of fish and game clubs by Massachusetts, Rhode Island, and Quebec. In Virginia no license is required of bona fide guests of residents, and in Ontario no fee is charged for a guest license.

Details in regard to hunting licenses are given in the table on pages 52–59. In every case the fee includes the amount charged for issuing the license. The term commissioner unless otherwise qualified means the game or fish commissioner.

[1] Except in a few counties.

[2] Including Tennessee, which has only an optional license; otherwise 39 States have a general resident license.

[3] On wild lands of the State, except from December 1 to 15.

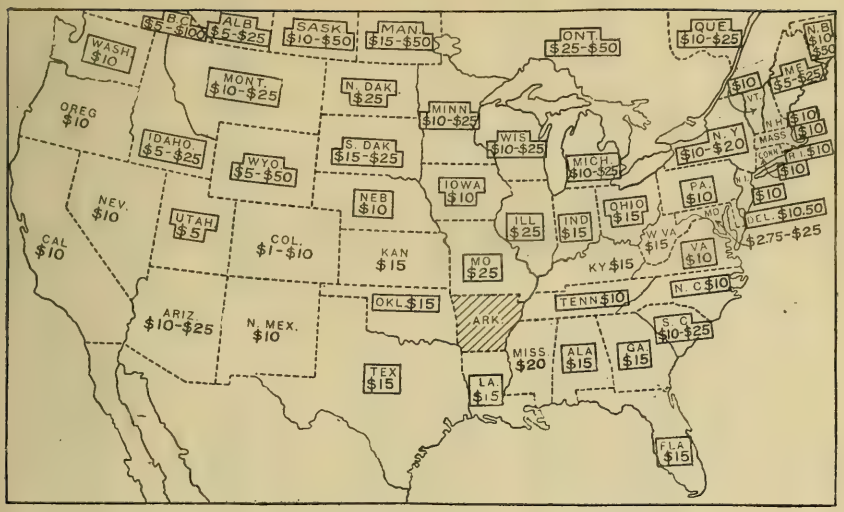

FIG. 2.—States and Provinces which require nonresidents to obtain hunting licenses.

[Inclosed names indicate the States which specifically permit licensees to take a limited amount of game out of the State. Alaska and Newfoundland have $50, Nova Scotia $30 and $15, and Prince Edward Island $15 nonresident licenses, with export privileges. Arkansas does not permit hunting by nonresidents, except in a few counties.]

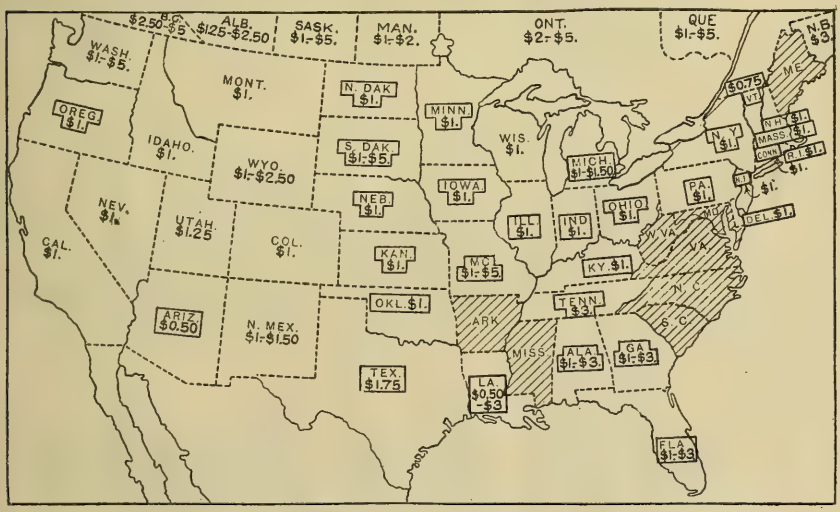

Fig. 3.—States and Provinces which require residents to obtain hunting licenses.

[In Connecticut, Delaware, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, and Rhode Island an additional fee of 10 to 25 cents is charged for issuing the license. Inclosed names indicate States which permit residents to hunt on their own land without license. Nova Scotia and Newfoundland have $5 resident licenses for hunting caribou. Note that many of the States adopt the French method of exempting landowners, while some, particularly in the West, follow the English method of requiring everyone who hunts to obtain a license.]

Details of hunting licenses and export regulations.

State.	Kind of license.	Fee.	By whom issued.	Details of license.	Export limit.
Alabama	Nonresident	$15.00	Probate judge	Not required on lands owned or leased by hunter. Expires Dec. 31.	Game lawfully killed by licensee.
	Alien	15.00	do	do	
	Resident	3.00	do	State license; required outside of county of residence, except on lands owned or leased by hunter.	
	do	1.00	do	County license; not required on lands owned or leased by hunter. Expires Dec. 31.	
Alaska	Nonresident	50.00	Governor	Expires Dec. 31	2 moose (north of lat. 62°), 4 deer, 3 caribou, 3 sheep, 3 goats, and 3 brown bears.
	Alien (nonresident)	100.00	do	do	
	Guide		do	American citizen or native of Alaska. Fee fixed by governor.	
	Shipping (resident)[1]	40.00	do	Export of heads or trophies by resident	1 moose (north of lat. 62°), 4 deer, 2 caribou, 2 sheep, 2 goats, and 2 brown bears.
	do	10.00	do	do	1 caribou or sheep.
	do	5.00	do	do	1 deer, goat, or brown bear.
	Shipping (special)[1]	150.00	do	Export of moose from southern Alaska	1 moose, south of lat. 62°.
Arizona	Nonresident	25.00	Warden or license collector	Deer licenses not required for hunting on own land	Under permit. See Export, p. 38.
	do	10.00	do	Birds	
	Alien	100.00	do	Deer	
	do	25.00	do	Birds	
	Resident[2]	.50	do	General. Duplicate license, 10 cents	
Arkansas				Nonresidents not permitted to hunt[3]	No export.
California	Nonresident	10.00	Fish commissioner, county clerks.	Expires June 30	No export.
	Alien	25.00	do	do	
	Resident	1.00	do	do	
Colorado	Nonresident or alien	10.00	Commissioner or county recorder.	Expires Dec. 31	Permit required from commissioner.
	do	2.00	do	County license for birds, good for 1 week	
	do	1.00	do	County license for birds, good for 1 day	
	do	12.00	do	Hunting and fishing license. Expires Dec. 31	
	Resident	1.00	do	do	
	Guide	5.00	Commissioner	Must also have State hunting license	
Connecticut	Nonresident	10.25	City or borough clerk	Expires Dec. 31	No quail, ruffed grouse, or woodcock.
	Alien	15.25	do	do	
	Resident (citizen)[4]	1.25	do	do	
Delaware	Nonresident	10.50	Commission	Expires Dec. 31	See p. 39.
	Resident	1.10	do	Not required of owners or tenants or their children hunting on their estates. Expires Dec. 31.	
Florida	Nonresident or alien	15.00	County judge	County license	Game lawfully killed by licensee.
	Resident	3.00	do	State license	
	do	1.00	do	County license; not required on own land or in ward of residence.	

Georgia	Nonresident	15.00	Commissioner or county warden.	State license. Expires Feb. 1	Game lawfully killed.
	Resident	3.00	do	do	
	do	1.00	do	County license good only in county of residence; not required in militia district or on lands of holder. Expires Feb. 1.	
Idaho[6]	Nonresident or alien	25.00	Warden, and deputies	Big game. Expires Mar. 31	2 deer, 1 ibex, 1 mountain goat, 1 mountain sheep, 1 elk. No birds. (See p. 39.)
	do	5.00	do	Birds only	
	Resident citizen	1.00	do	Hunting and fishing. Not required of women or children under 12 years old.	
Illinois	Nonresident	25.50	City or county clerk	Expires June 1	Not more than 50 birds of all kinds.
	Resident	1.00	do	Not required of owners and tenants of farms hunting on their lands.	
Indiana	Nonresident	15.50	Clerk of circuit court	Good for 1 year	Nonresident: 15 birds of all kinds, or 45 in case of 3 or more days' consecutive hunting. Resident: No export.
	Resident[6]	1.00	Commissioner, clerk of circuit court.	Not required of landowners hunting on their own lands, nor of their children or tenants.	
Iowa	Nonresident	10.50	County auditor	Expires July 1	25 of all kinds of game.
	Resident	1.00	do	Not required of owners or tenants of farm lands, or their children, hunting on such lands.	
Kansas	Nonresident	15.00	Secretary of state	Not required of landowners hunting on their own premises. Expires June 30.	No export.
	Resident	1.00	County clerk	do	
Kentucky	Nonresident or alien	15.00	do	Expires Dec. 31	No quail, grouse, pheasant, wild turkey.
	Resident	1.00	do	Expires Dec. 31. Not required of landowners and tenants or members of their families hunting on their own premises or adjoining farms.	
Louisiana	Nonresident or alien	15.00	Tax collector	Not required of resident alien hunting on his own land. Good for season.	Nonresident: 1 day's limit of game if not for sale. Resident: No export.
	Market hunting	10.00	do	Issued to residents only	
	Resident	3.00	do	State license. Not required of person hunting on his own land.	
	do	.50	do	County license not required in ward of residence	

[1] Not more than one general ($40) license and two special ($150) moose licenses issued to one person in one year. Each shipper must file with customs office at port of shipment an affidavit that he has not violated the game law; that the trophy to be shipped has not been bought or purchased, has not been sold, and is not shipped for purpose of sale; that he is the owner of the trophy, and, in case of moose, whether the animal from which it was taken was killed north or south of latitude 62°.

[2] Not required of children under 17 years old if accompanied by holders of general license.

[3] But see State *v.* Mallory, 83 S. W., 955, deciding that nonresidents may hunt on their own land. A few counties make exceptions, and issue local licenses, viz, Bradley, Chicot, Clay, Crittenden, Dallas, Desha, Grant, Hot Spring, Jefferson, Lonoke, Monroe, Phillips, St. Francis, and Stone.

[4] No license is required of a bona fide resident of Connecticut, or his lineal descendants, hunting on land occupied by him and used for agricultural purposes.

[5] Not required of veterans of the Civil War.

[6] Applicant under 14 years old must furnish written consent of parent or guardian.

Details of hunting licenses and export regulations—Continued.

State.	Kind of license.	Fee.	By whom issued.	Details of license.	Export limit.
Maine	Nonresident	$25.00	Commissioners	All game during October, November, and December	Nonresident: 1 moose, 2 deer, 10 each of partridges and woodcock, 15 ducks; also one pair of game birds a month under 50-cent tag.
	do	5.00	do	Game that may be shot before Nov. 1 in certain counties. Holder may obtain big-game license by paying $20 additional.	
	do.[1]	5.00	do		
	Resident alien	15.00	do	Not required of aliens who pay taxes or who have resided in State 2 years continuously prior to application.	
	Camp keeper	5.00	do		
	Guide (nonresident)	20.00	do	Guide to be registered, and to guide not more than 5 persons at a time. Expires Dec. 31.	
	Guide (resident)	1.00	do	do	
	Shipment (resident)		do	Moose, $5; deer, $2; one pair of game birds in seven days, 50 cents.	
Maryland	Nonresident [2]	$5.00 / 25.50	Clerk of circuit court [3]	Separate county laws	Local laws.
Massachusetts [4]	Alien	15.00	City or town clerk	Required of unnaturalized foreign-born residents	
	Nonresident	[5] 10.00	Commissioners	Expires Dec. 31	10 birds of all kinds.
	Resident	1.00	City or town clerk	Not required of persons hunting on land which they own or on which they live.	
Michigan	Nonresident or alien	25.00	County clerk	Deer	1 deer under permit. 1 day's bag limit of birds.
	do	10.00	do	Small game only. Not required of persons hunting on their own lands.	
	Resident	1.50	do	Deer. Good for season	
	do	1.00	do	Small game. Not required in county of residence or of landowners, their minor children, or employees hunting on own land.	
	Export	10.00	State warden		Nonresident landowner and member of a club maintaining a game preserve may export 20 ducks or migratory birds killed by him on said premises.
Minnesota	Nonresident	25.00	Commissioners	Game animals. Expires Dec. 31	1 deer, 25 birds.
	do	10.00	do	Game birds	
	Resident	1.00	County auditor	Deer and moose. Expires Dec. 31	
	do	1.00	do	Game birds. Not required in county of residence. Expires Dec. 15.	
Mississippi	Nonresident	20.00	Sheriff	County license. Landowners and their nonresident relatives and friends hunting on their lands exempt. Good for season.	No export.
Missouri	Nonresident	25.00	Commissioner	Expires Dec. 31	2 deer, 4 turkeys, 50 of other species.
	Resident	5.00	County clerk or license collector.	State license. Expires Dec. 31	
	do	1.00	do	County license. Required for hunting in county of residence or in adjoining counties. Not required of owners or tenants of farm lands hunting on such lands. Expires Dec. 31.	

Montana	Nonresident	25.00	Warden	Hunting and fishing. Expires Apr. 30	
	do	10.00	do	Hunting and fishing. Birds only	Number permitted to be killed (see p. 49).
	Alien	30.00	do	do	
	Resident [6]	1.00	Warden or justice of peace	do	
	Guide	10.00	Warden	Good for 1 year	
	Shipping	.50	do	Permits limited export in open season	
Nebraska	Nonresident	10.00	Commissioner or county clerk.	Hunting and fishing. Expires Dec. 31	50 birds.
	Resident	1.00	do	Hunting and fishing. Not required of boys under 18 accompanied by parents or guardians, or of persons hunting on lands they own or occupy.	
Nevada	Nonresident	10.00	County clerk or warden	Not required of women, of children under 14, or of persons hunting on their own lands.	No export.
	Alien	25.00	do	Good for 1 year	
	Resident	1.00	do	do	
New Hampshire [7]	Nonresident or alien	10.00	Commissioner	Expires Dec. 31. Not required of landowner (or immediate family) hunting on his own land.	2 deer, 12 birds.
	Resident	1.00	Commissioner and town clerk.	do	
	Guide	1.00	Commissioner	Resident. Expires Dec. 31	
	do	20.00	do	Nonresident. Expires Dec. 31	
New Jersey	Nonresident	10.50	County clerk	Expires Dec. 31	10 rabbits, 50 reedbirds, 50 rail, and 15 other birds a day.
	Alien	10.50	County, city, or town clerk.	Not required of owner or lessee of farm land hunting on land on which he resides.	
	Resident citizen	1.15	do	Not required of landowner or members of family residing on his land and hunting thereon.	
New Mexico	Nonresident or alien	10.00	Warden or deputy	Nonresident paying taxes to amount of $100 entitled to a resident license.	Under permit.
	Resident	1.50	do	General	
	do	1.00	do	Big game, including turkeys	
	do	1.00	do	Game birds, except turkeys	
	Guide	5.00	do		

[1] For game that may be shot before Oct. 1 in Aroostook, Franklin, Hancock, Oxford, Penobscot, Piscataquis, Somerset, and Washington Counties.

[2] County and local licenses are issued at the following rates, including clerk fees: Allegany, $10.50; Baltimore, resident of State, $5.20, nonresident of State, $20.20 (rabbit, squirrel, quail, grouse, jacksnipe); Calvert, $10.50; Caroline, $5; Carroll, $10.50; Cecil, $10 (rabbit, quail, grouse, woodcock, blackbird, reedbird, rail, plover, and crowbill, teal, mallard, sprigtail, black, and summer ducks); Charles, $20.50 (rabbit, quail, and woodcock); Dorchester, of State, $10; of county, $5; Frederick, $15.50; Garrett, $25.50; Harford, $10.50 (all game except waterfowl); Howard, $8; Kent, $15.50, $5.50 if invited by landowner (all game except waterfowl); Montgomery, $15.50; Patuxent River, $11 (club license, $50); Prince George, $20.50 (upland game); Queen Annes, $4.50; St. Marys, $20.50 (upland game); Somerset, resident of State, $2.75, nonresident of State, $10.50; Talbot, $10 (upland game); Washington, $10.50 (not required if written permission be secured from landowner or lessee); Wicomico, $10.50; Worcester, $10 (wild fowl). Guests of landowners require no license, except in Allegany, Baltimore, Caroline, Cecil, Dorchester, Garrett, Kent, Somerset, Talbot, and Worcester Counties. (Dorchester grants the privilege if the nonresident be a relative of his host.) Anne Arundel prohibits hunting by nonresidents of the county except by permission of landowners, and Charles prohibits hunting of waterfowl by nonresidents. In several counties residents pay special licenses as follows: Baltimore, $1.20 (rabbit, squirrel, quail, grouse, jacksnipe); Anne Arundel, pusher, $2, booby and brush blind (west side of Chesapeake Bay), $5 (South River), $2.50; Cecil (on Bohemia and Elk Rivers), sneak boat, $5.50 (on Bohemia, Elk, and Sassafras Rivers), sink box, $10.50; Dorchester, $1; Harford, sneak boat, $5.75, sink box, $20.75; Patuxent River, pusher, $2.50; Queen Annes, booby blind, $2.50, sink box, $10.50; Susquehanna Flats, sneak boat, $5.75, sink box, $20.75; Talbot, Dickinson Bay, sink box or blind, $5.

[3] In Cecil County by the Cecil County Game Protective Association.

[4] Applicants for license under 16 years old must furnish written consent of parents or guardians.

[5] Members of incorporated game clubs owning real estate assessed at not less than $1,000 and organized prior to 1907, owners or their minor children over 18 years old of real estate assessed at not less than $500, or nonresidents invited (for not more than 4 days) by members of incorporated club for hunting foxes, pay a fee of $1.

[6] United States soldiers stationed in the State and officers of the United States Forest Service classed as residents.

[7] Licenses not issued to boys under 18 without written permission of parent or guardian.

Details of hunting licenses and export regulations—Continued.

State.	Kind of license.	Fee.	By whom issued.	Details of license.	Export limit.
New York	Nonresident or alien.	$20.50	County, city, or town clerk.	Fee for nonresident taxpayer, $10.50. Alteration, transfer, or loan of license a forgery in second degree. Expires Dec. 31.	1 deer, and day's bag limit under shipping license.
	Resident	1.10	do	Alteration of license a forgery. Not required of owner or lessee (or immediate family) occupying and cultivating farm land and hunting on such land.	
North Carolina	Nonresident (Audubon).	10.25	Clerk of superior court	Good only in 37 counties not covered by following and 3 local licenses. Not required of parents and children of landowners hunting on their grounds.	50 partridges or quail, 12 grouse, 2 turkeys, 50 beach birds or snipe.
	Nonresident (special).[1]	10.50	do	Good only in county of issue	
North Dakota	Nonresident	25.00	County auditor	Expires Dec. 15	Nonresidents only. 2 deer; 20 (in all) of grouse, prairie chickens, doves, cranes, and swans; 50 (in all) of plover, snipe, ducks, geese, and brant. Resident; no export.
	Resident[2]	1.00	do		
Ohio	Nonresident	15.25	Clerk county court or town clerk.	Expires Dec. 5	25 animals and birds.
	Resident	1.25	do	Expires Dec. 31. Not required of landowner, his children, or tenant hunting on own land.	
Oklahoma	Nonresident	$15.00	Warden or county clerk	Expires May 1	2 days' bag limit.
	Alien	25.00	do	do	
	Resident citizen	1.25	do	Not required of minor under 14 years, or person hunting on his own or leased lands.	
Oregon[3]	Nonresident	10.00	County clerk	Not required of landowner and family hunting on own premises. Expires Dec. 31.	No export allowed, except by Washington hunters, who may take 1 day's bag.
	Alien	25.00	Commission	Gun license does not permit hunting	
	Resident	1.00	County clerk	Hunting and fishing. Not required of landowner and family hunting on own premises.	
Pennsylvania	Nonresident	10.00	County treasurer	Good for year of issue. Aliens not permitted to hunt.	1 day's bag limit.
	Resident[3]	1.15	County treasurer or justice of the peace.	Expires Dec. 31. Children 14 not permitted to hunt. Not required of citizen landowner, his family, or tenants hunting on land or land adjacent thereto under permit.	
Rhode Island[3]	Nonresident[4]	10.15	City or town clerk	Expires Dec. 31	10 birds.
	Alien	15.15	do		
	Resident	1.15	do	Not required of owner or occupant of agricultural land (or immediate family) hunting on such land.	
South Carolina	Nonresident and alien.	10.25	County clerk	All game except quail and turkeys. Good for season.	2 deer, 4 wild turkeys, 12 ruffed grouse, 50 each of partridges (quail), beach birds, ducks, geese.
	do	25.00	do	County license for quail and turkeys. Not required of person hunting on land he owns or controls or guest of and accompanied by resident freeholder.	
	Market hunting	50.00	County treasurer	County license for residents hunting wild fowl on public lands and navigable waters. Expires Dec. 31.	

South Dakota	Nonresident	25.00	Warden or county treasurer.	Big game and game birds. Expires June 30	Birds lawfully in possession.
	do	15.00	do	Game birds only	
	Resident	5.00	County treasurer	County license. Big game. Issued in county in which hunting is to be done.	
	do	1.00	do	Game birds. Not required of landowner hunting on his own land.	
Tennessee	Nonresident	10.25	State warden	Not required of landowner paying $100 taxes. Expires Dec. 31.	Nonresident: 50 ducks; 30 of all other birds in aggregate. Resident: No export.
	Resident	3.00	do	Required when hunting on lands with verbal permission of owner.	
	Market hunting	25.00	do	Annual license; $200 bond required	
Texas	Noncitizen	15.00	Commissioner	Expires Dec. 31	3 deer, 75 ducks, 1 day's bag limit of other birds.
	Resident	1.75	County clerk	Not required in county of residence or adjoining counties or on land controlled by hunter. Expires Sept. 1.	
Utah	Nonresident	5.00	Commissioner or justice of peace.	Hunting and fishing. Expires Dec. 31. Not required for rabbits.	Nonresident: 1 day's bag limit. Resident: No export.
	Alien	15.00	do	do	
	Resident	1.25	do	Hunting and fishing. Not required of females or children under 12 or for hunting rabbits.	
Vermont [3]	Nonresident [5]	10.50	Town clerk	Expires July 1	Nonresident: 1 deer; birds as stated on p. 38. Resident: 1 season's bag under license.
	Resident	.75	do	Not required of owners or tenants of farm lands (or their minor children) hunting on such lands.	
Virginia [6]	Nonresident [7]	10.00	County clerk	Good in open season in the 6 months following issue	1 deer, 50 quail, 10 pheasants or grouse, 3 wild turkeys, 25 of each or 100 in all, plover, snipe, sandpipers, willets, curlew, and tatlers.
Washington	Nonresident	10.00	State auditor	State license. Expires Mar. 1	Nonresident or nonresident alien: A season's limit of big game and a day's limit of birds. Resident: No export.
	do	5.00	County auditor	County license	
	Alien, nonresident	50.00	State or county auditor	State or county license	
	Alien	15.00	State auditor	Gun license. Consular certificate required	
	Resident	5.00	do	State license	
	do	1.00	County auditor	County license	
West Virginia	Noncitizen	15.50	County clerk	County license. Good for 1 year; written consent of parent or guardian required if applicant is under 15.	No deer, quail, ruffed grouse, pheasants, wild turkeys.

[1] Issued in the following 58 counties: Beaufort, Bertie, Cabarrus, Camden, Carteret, Caswell, Catawba, Chowan, Clay, Cleveland, Currituck, Dare, Davie, Duplin, Forsyth, Franklin, Gaston, Gates, Graham, Halifax, Harnett, Henderson, Hertford, Hyde, Jackson, Johnston, Jones, Lincoln, Macon, Madison, Martin, Mitchell, Montgomery, Nash, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Pitt, Polk, Randolph, Richmond, Robeson, Sampson, Stanly, Stokes, Swain, Transylvania, Tyrrell, Union, Vance, Warren, Washington, Wayne, Wilkes, Wilson, Yadkin. Special license provisions are in force in Alexander (also quail export limit), Caswell, Clay, Craven, Dare (wildfowl), Gaston, Granville, Haywood, Hyde, Jackson, Lincoln, Northampton, Pamlico, and Warren Counties. Details of these are given in Poster No. 30, copies of which may be had free on application to the Biological Survey, U. S. Department of Agriculture.

[2] Not required of owner or occupant of agricultural lands or members of his immediate family hunting on such lands.

[3] *Oregon:* Children under 14 years old not permitted to hunt with gun except on own premises or those of parent, relative, or guardian. In *Pennsylvania* and *Vermont*, applicants under 16 years old must furnish written consent of parent or guardian. In *Rhode Island*, applicant must be 15 years old.

[4] Nonresident citizens and members of hunting or fishing clubs incorporated prior to Jan. 1, 1909, owning real estate to the value of $1,000, and nonresident citizens owning real estate assessed at not less than $500, pay a fee of $1.15.

[5] Fee 75 cents for owner of improved real estate in Vermont appraised at $1,000 who pays taxes thereon.

[6] Rappahannock County requires written and duly acknowledged permission (good for 4 months) before permitting hunting or trapping on another's land.

[7] Guests not required to procure license to hunt on land of host, provided the host receives no compensation, directly or indirectly, from such guest and hunts with him.

Details of hunting licenses and export regulations—Continued.

State.	Kind of license.	Fee.	By whom issued.	Details of license.	Export limit.
Wisconsin [1]	Nonresident	$25.00	Secretary of state	All game	Nonresident: 1 deer, 30 birds. Resident: No export.
	do	10.00	do	All game except deer	
	Resident [2]	1.00	County clerk		
Wyoming	Nonresident or alien.	50.00	Justice of peace	Hunting and fishing. Expires Dec. 31	2 elk, 1 male deer, 1 male sheep, 20 game birds.
	Nonresident	10.00	do	Bear only	
	do	5.00	do	Hunting and fishing. Birds only	
	Alien	5.00	do	Birds only	
	Resident [3]	2.50	Justice of peace or game warden	Ordinary	
	do	15.00	do	1 additional elk	
	do	1.00	Justice of peace	Birds only. Licensee must be over 14 years old	
	Guide [4]	10.00	do		
CANADA.					
Alberta	Nonresident	$25.00	Minister of agriculture	General. Expires Dec. 31	Nonresident: Under general license, trophies of big game legally killed. Resident: No export.
	do	5.00	do	Birds only. Expires Dec. 31	
	Guide, camp help	5.00	do	Resident maximum fee. Expires Dec. 31. Shall not guide.	
	Resident [5]	2.50	do	Big game. Expires Dec. 31	
	do	1.25	do	Birds. Required of residents of city or town south of Township 59.	
	Market hunting	5.00	do	Expires Dec. 31	
British Columbia [6]	Nonresident	100.00	Warden or any Government agent.	Members of Army, Navy, or Militia in actual service exempt.	Heads, hides, and horns of animals legally killed by licensees.
	do	50.00	do	Birds only. Good Sept. 1–Mar. 31	
	do	25.00	do	Bear. Good Jan. 1–July 15	
	do	5.00	do	Birds only. British subject. Good for 1 week	
	Resident	2.50	do	Birds and deer only	
	do	5.00	do	Birds and all big game	
	do	10.00	do	Birds, all big game, and trapping	
	Guide	5.00	do		
Manitoba	Nonresident	50.00	Minister of agriculture	Expires Dec. 31	2 heads and skins each of game animals, 1 big game animal and 50 ducks, 100 geese or swans, other game birds, except partridge, grouse, and prairie chicken under permit.
	do	15.00	do	British subject	
	Resident	2.00	do	Big game only	
	do	1.00	do	Birds only. Required of resident of city or town	
New Brunswick [6]	Nonresident	50.00	Surveyor general	Moose, caribou, and deer	No partridge; other game under permit.
	do	25.00	do	Game birds. Special license for Westmoreland County	
	do	10.00	do	2 deer only. Discretionary with surveyor general	
	do	10.00	do	Game birds	
	Resident	3.00	do	Moose, caribou, and deer	
	Sinkbox	1.00	do	For shooting geese and brant	
	Guide	1.00	do	Resident accompanying anyone hunting big game	
	Camp help	1.00	do	Resident	
	do	50.00	do	Nonresident	

Newfoundland	Nonresident	51.00	Game and fisheries board	Good for season. Can not employ unlicensed guide	3 caribou under license and permit.
	Guide	50.00	do	Nonresident. Resident guide licenses free	
	Resident	5.00	do	3 caribou not for traffic	
	Householder		do	do	
Nova Scotia [6] [7]	Nonresident	30.00	Provincial secretary, game commissioners or county clerk.	All game. Expires Aug. 1	1 moose lawfully killed by licensee.
	do	15.00	do	Birds and small game, except woodcock and snipe	
	Resident	5.00	do	For caribou outside county of residence	
	Guide	2.00	do	Resident. Expires Aug. 1	
Ontario	Nonresident	50.00	Superintendent of game		
	do	25.00	do	Ducks and other small game	100 ducks lawfully killed by licensee.
	Resident	5.00	do	Moose and caribou	
	do	2.00	do	Deer	1 deer, 1 bull moose, 1 bull caribou lawfully killed by licensee.
	Guest		do	No fee required. Good for 1 week or less	
	Guide	2.00	do	Expires Dec. 31	
Prince Edward Id	Nonresident	15.00	Game inspector or tax collector.	All game. Expires 1 year after date	12 birds (except geese and brant).
Quebec	Nonresident	25.00	Minister of colonization	All game	
	do	10.00	do	Issued to members of incorporated hunting clubs	
	Resident	1.00	do	Big game. Not required of person hunting for own use	
	do	5.00	do	3 deer and 3 caribou additional to bag limit	
Saskatchewan [8]	Nonresident	50.00	Minister of agriculture	Big game only. Expires Dec. 31	Tropnies of big game under permit.
	do	25.00	do	Birds only. Expires Dec. 31	Limited amount under permit.
	do	10.00	do	Birds only. Good for 6 days	
	Resident	5.00	Minister or agent	Big game. Expires Dec. 31	
	do	1.00	do	Birds only. Required of resident of city or town	
Yukon	Nonresident	100.00	Commissioner or game guardian.	All game	Head of 1 moose, 1 caribou, 1 sheep, or 1 goat.

[1] Bona fide settler who has not resided in the State 1 year may take out a special resident license.
[2] Owner or occupant of land or member of his family may hunt rabbits at any time and squirrels during open season on such land without license.
[3] Applicant must be an elector of the State; child or ward, over 14 years, of an elector; a soldier or sailor of the United States and an elector thereof, stationed 1 year at a post in the State; or a nonresident paying $100 or more taxes on property owned in the State. Soldier or sailor must employ guide.
[4] Guide must be citizen and qualified elector of State who is a freeholder or has a valid filing on public lands in the State, must act as assistant game warden, and is equally responsible with employer for violation of law.
[5] Farmers or their sons residing on own land, fee $1.
[6] Nonresident hunting big game must be incharge of a registered guide.
[7] Nonresident paying taxes on real estate to the amount of the license fee, required to pay only $5.
[8] Written consent of parent or guardian required if applicant is under 16 years of age.

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VITRIFIED BRICK AS A PAVING MATERIAL FOR COUNTRY ROADS.

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INTRODUCTION.

A clay product closely resembling our present-day brick was among the earliest materials used for paving streets and roads. The first brick pavement constructed in this country, however, dates back no further than 1872; and to Charleston, W. Va., belongs the distinction of having been the first American city to employ brick for paving.

For a number of years after being introduced into this country the use of paving brick was principally confined to city streets, and, owing to frequent inferiority in the quality of the brick and lack of care in construction, very few of the early pavements proved satisfactory. Even now, after the experience of 40 years has demonstrated that it is entirely practicable to construct satisfactory brick pavements when proper care is exercised, and that much waste results from the use of poor materials or faulty construction, instances can frequently be found where brick pavements have wholly or partially failed from causes which might easily have been prevented.

Country roads paved with vitrified brick are becoming quite common in many of our States, and, owing to the general satisfaction which these roads are giving when properly constructed, it is probable that their mileage will continue to increase rapidly. The principal advantages which brick roads possess may be stated briefly as follows: (1) They are durable under heavy traffic conditions; (2) they afford easy traction and good foothold for horses; (3) they are easily maintained and kept clean; and (4) they present a very pleasing appearance.

The principal disadvantage is the high first cost. The defects which frequently result from lack of uniformity in the quality of the brick or from poor construction are usually to be traced indirectly to an effort to reduce the first cost or to a popular feeling that local materials should be used, even when of inferior quality.

This bulletin purposes to furnish information relating to the construction of brick roads, and to supply suggestions for aiding engineers in preparing specifications under which such work may be satisfactorily performed. One of the most essential features of the construction of brick pavements is the selection of the brick, since the success or failure of such pavements depends to a large extent on the character of the material used. In order that the significance of the varying physical characteristics observed in brick manufactured under different conditions may be more readily understood, a brief discussion of the raw materials and processes used in the manufacture of brick will be given.

THE RAW MATERIALS.

Paving brick are made from shales and fire clays. The "lean" or less refractory varieties of these materials, which are found in the carboniferous deposits broadly distributed throughout the United States, are best adapted for this purpose.

Shales frequently occur in such quantity and are so located that they may be readily excavated by means of a steam shovel or other mechanical device. Occasionally, however, the deposits are comparatively thin and underlie other material, making it necessary that they be mined. Fire clays are usually found interstratified with coal deposits which may or may not be workable, and must, therefore, generally be mined. The principal difference between fire clays and shales, in so far as the manufacture of brick is concerned, is essentially a difference of color in the finished product. The shales always contain iron in some form, and brick made of shale are usually red. Fire clays are free from iron and should produce a light-colored brick. Some low-grade fire clays, however, may be darkened by certain firing conditions too complicated to be discussed in detail here.

Shales and fire clays as they occur in nature are not always well suited for use in the manufacture of paving brick, but must frequently be subjected to some modifying treatment before being used. In general, deposits of these materials occur in layers or strata, and the different strata are almost always slightly dissimilar in both physical and chemical composition. By carefully mixing the materials from different strata or from different parts of the bank, therefore, a resulting material of the desired character may usually be obtained. It not infrequently happens, however, that in order to secure the best results sand or surface clay must be added in an amount depending on the relative "leanness" or "fatness" [1] of the material used. In this connection it may be noted, also, that a chemical analysis of a given fire clay or shale does not necessarily

[1] "Leanness" and "fatness" refer respectively to the lesser or greater amount of silica present in the material.

indicate its fitness or unfitness for paving brick. The reason for this is that the quality of the brick after "firing" is no less dependent on the physical arrangement of the minerals than on the chemical composition of the material.

THE MANUFACTURE.

The general processes of manufacture are the same for both fire clays and shale. The raw material in either case is crushed to comparatively small fragments and conveyed by some convenient means to a grinding machine, known in the industry as a dry pan. Briefly, this machine consists of a solid iron plate, approximately 5 feet in diameter, surrounded by a perforated iron surface about 2 feet wide. Outside the perforated surface is a rim some 15 inches in height which serves to prevent the material from escaping otherwise than through the perforations. Upon the solid plate rest two massive crushers or mullers, each weighing from 2½ to 3 tons. The pan is revolved rapidly, causing the mullers to rotate by friction. The material is ground between the mullers and the plate and thrown out by centrifugal force toward the rim, where it escapes through the perforated surface into an elevator, by means of which it is conveyed to the screens.

The particles too large to pass the screens, which should not exceed three-sixteenths inch in mesh, are returned to the dry pan, while the screened material is passed to the mixing machine or pug mill by means of conveyors. In the pug mill, water is admixed with the clay to form a stiff mud, which is fed continuously into the brick machine proper.

The brick machine is an extremely heavy mechanism. It consists essentially of an auger or propeller conveyor, a tapering barrel, and the die or former. The material is forced by means of the auger conveyor into the tapering barrel, which terminates in the die, and issues from the die in a solid column under heavy pressure. For "side-cut" brick this column is approximately 4½ inches by 10 inches in cross section, and the brick are formed by cutting through the column, by means of an automatic device, at intervals of about 3½ inches. For "end-cut" brick the column has a cross section approximately 4 inches by 4½ inches and is cut into sections about 10 inches long.

Paving brick, whether end or side cut, have usually in the past been re-pressed. This process smooths and rounds the corners, and forms on one side of each brick small lugs or projecting trademarks which serve to produce uniform spacing between the courses of the pavement. Suitable lugs may also be formed at the time the brick are cut, however, and the process of re-pressing is then omitted. Much discussion has taken place as to which of these methods pro-

duces the better brick, and each method has many advocates. Entirely satisfactory pavements have been made from both re-pressed and unre-pressed brick, however, and it is very doubtful if the failures which have been observed in connection with either type could rightfully be attributed to this particular feature in the process of manufacture.

Special shapes, such as nose bricks for use next to car tracks, and hillside block, which have one side thicker than the other and which are used on steep grades in order to give the pavement a rough surface, may be made either by special die or special re-press molds.

The next step in the process of manufacture consists in drying the brick. In a properly systematized plant the brick are stacked upon drier cars as they leave the presses in such manner as to permit a free circulation of air between them. The loaded cars are immediately run into a tunnel drier, the temperature of which is maintained at about 100° F. at the entering end. As cars containing "green" brick enter one end of the tunnel, which is usually more than 100 feet long, other cars containing dry brick are being removed at the opposite end. Air circulation in the dryer is effected by means of fans or high stacks. During drying the brick lose an amount of moisture equivalent to from 15 to 20 per cent of their own weight.

The brick leave the dryer ready for burning, which is the last and undoubtedly the most important step in the process of manufacture. Upon the burning depends largely the quality of the finished product, and it requires the greatest skill so to regulate the temperatures and firing periods as to obtain the best results from a given material. Experience alone can demonstrate the manner in which the burning must be modified in order to suit varying sets of conditions. The kilns in which the burning is done are made of brick and are provided with numerous furnaces. The brick are placed in the kilns so as to permit a free circulation of the gases of combustion and the heated air.

PHYSICAL CHARACTERISTICS.

GENERAL REQUIREMENTS.

Paving brick should be uniform in size, reasonably perfect in shape, and free from ragging, due to friction in the die, or kiln marks, caused by impressions from overlying brick in burning. They should be tough in order to resist crushing, hard in order to resist abrasion, and uniformly graded in order that the pavement may wear evenly. Each brick should be homogeneous in texture and free from objectionable laminations or seams. Fire cracks, caused by too rapid firing, should be limited in number and extent, and the entire brick should be vitrified and should contain neither unfused nor glassy spots.

COLOR.

The color is a valuable guide in inspecting brick from the same plant, but it is of little importance when the brick to be compared are from different factories. For brick manufactured from a particular raw material the color indicates, in a measure, the temperature to which they have been subjected, provided they have been burned under identical conditions. Ordinarily, the darker the color, the higher the temperature and, presumably, the better the brick. The surface color of brick may be very misleading, however, and the color of the interior should be used in making comparisons.

SPECIFIC GRAVITY.

The specific gravity of paving brick was formerly considered of importance in judging their fitness for use in pavements. It has since been generally conceded, however, that a knowledge of the specific gravity is of comparatively little value. The specific gravity of shale brick is ordinarily between 2.20 and 2.40, and of fire-clay brick between 2.10 and 2.25.

ABSORPTION.

The absorptive power of brick, like their color, is a matter of very slight importance, except for comparing specimens manufactured under identical conditions. It is true that the porosity of the brick increases with the power of absorption, but it is very doubtful if any paving brick possessing an objectionably high absorptive power could pass even a very casual inspection. In other words, a high degree of porosity always manifests itself in other ways more clearly than in the ability of the brick to absorb water.

CRUSHING STRENGTH.

The crushing strength of good paving brick varies from 10,000 pounds to 20,000 pounds per square inch when the load is applied uniformly over the entire top surface of the test specimen, and may be much greater if the area over which the load is applied is less than that of the top surface. Since paving brick in use are seldom required to withstand a pressure of more than about 2,000 pounds per square inch and since inferior brick may possess relatively very high resistance to crushing, a knowledge of the crushing strength is clearly of little value in comparing the relative excellence of different makes of brick. It is, therefore, usually considered unnecessary to specify a definite requirement as to the crushing strength of paving brick.

TESTING THE BRICK.

Definite methods of testing paving brick have been in general use for only a comparatively few years and have only recently undergone a pronounced change. The object of all tests is to determine

whether or not a given quality of brick is suitable for use in constructing pavements and to furnish a basis for comparing different classes of brick. The methods have, therefore, been repeatedly changed, not only in order to make the results obtained indicate more definitely the quality of the brick, but also with a view to establishing uniformity, so that results obtained in different laboratories may be intelligently compared. A discussion of the most important tests follows in more or less detail.

FIELD TEST.

The general appearance of a paving brick is, to an experienced eye, a valuable indication of its quality, and will frequently suggest the advisability of applying routine tests to some particular part of a shipment. Unfortunately, however, the knowledge gained from experience with one kind of brick can not be safely relied upon in inspecting other brick made by a different process or from a different class of raw material. A further limitation to this method of testing lies in the fact that the results obtained do not admit of numerical evaluation, and can not, therefore, be very accurately described. This test is nevertheless valuable, and since no apparatus other than a hand hammer is needed, it can always be employed.

The test consists simply in making a careful inspection of the brick individually and collectively. The size is tested by making measurements, the shape by arranging a number of brick in the order in which they are intended to be placed, and the quality by an examination of both the exterior and interior of a number of samples.

TRANSVERSE TEST.

The transverse strength of a brick is determined by supporting it upon two knife edges and applying a load on the opposite side and midway between the supports by means of a third knife edge. The load is gradually increased until rupture occurs, and the result of the test is expressed in terms of the ratio $\frac{3\ P\ 1}{2bd^2}$, called the modulus of rupture. In the above ratio P represents the breaking load in pounds, while 1, b, and d represent, respectively, the distance between supports, the breadth of the specimen, and the depth of the specimen, all measured in inches.

The modulus of rupture for good paving brick usually lies between 2,000 and 3,000, and frequently varies considerably even with carefully selected specimens which have been manufactured under identical conditions. In making this test a considerable number of specimens should be used, and the requirements concerning the transverse strength should be no less definite as to uniformity in the results of the test than as to the average modulus of rupture.

RATTLER OR ABRASION TEST.

The rattler or abrasion test is undoubtedly the most important of the tests made on paving brick at present. In making this test the specimen brick are subjected to destructive influences very similar to those encountered in actual service, and the results obtained, therefore, indicate very closely the effect which traffic may be expected to produce on a pavement constructed of similar brick. The methods of making the test, of which there were formerly a great many, have undergone repeated changes in order that service conditions may be more nearly approached and also in an effort to bring about uniformity, so that the results obtained may be of the greatest possible scientific value. The method which has been lately recommended by the subcommittee on paving brick of the American Society for Testing Materials may be briefly described as follows:

The apparatus necessary for making the test, ordinarily called the rattler, consists of a 14-sided barrel of regular polygonal cross section supported on a suitable frame and fitted with the necessary driving mechanism. The staves, each of which forms a side of the barrel, are made of 6-inch 15.5-pound structural steel channels 27¼ inches long. These staves are double bolted to the cast-iron heads of the barrel, which are provided with slotted flanges for holding the bolts. Cast-iron wear plates are bolted to the inside of the barrel heads. The outside diameter of the barrel is 28⅜ inches.

In this barrel is placed what is known as the abrasive charge. This charge consists of two sizes of cast-iron spheres having respective diameters of 3¾ inches and 1⅞ inches and weighing, respectively, 7.5 pounds and 0.95 pound when new. Ten of the larger spheres are used, and the number of the smaller spheres is made such that the weight of the entire charge will approximate 300 pounds. The individual larger spheres are discarded whenever their weight falls to 7 pounds or less and the smaller spheres when they become sufficiently worn by usage to pass through a circular opening having a diameter of 1¾ inches.

The test is made by placing a charge of ten representative brick, which have been previously dried at a temperature of 100° F. for at least three hours, in the barrel together with the abrasive charge, and then revolving the rattler 1,800 times. The number of revolutions per minute is not permitted to fall below 29½ nor to exceed 30½, and the operation is made continuous from start to finish.

The results of the test are reckoned in terms of the loss in weight sustained by the brick, and this loss is expressed as a percentage of the original weight of the brick tested. In determining the loss in weight, no piece of brick which weighs less than 1 pound is considered as having withstood the test.

Good paving brick will ordinarily lose from 17 per cent to 22 per cent of their original weight in the rattler test, and specifications concerning this loss should be prepared with a view to the character of the traffic for which the pavement is designed. Some reasonable requirement as to the loss sustained by any individual brick should also be made. This loss should ordinarily not exceed 25 per cent, and under severe traffic conditions a smaller percentage should be required.

CONSTRUCTION.

PREPARING THE SUBGRADE.

In forming a roadbed upon which a brick pavement is to be constructed, the essential features to be considered are (1) thorough drainage, (2) firmness, (3) uniformity in grade and cross section, and (4) adequate shoulders.

Thorough drainage can be secured for any particular road only by means of a careful study of the local conditions which affect the accumulation and "run-off" of both the surface and ground water. These conditions vary considerably even in the same locality, and no set of rules can be given which would cover all cases. For example, the material composing the roadbed may be springy, and in this case tile underdrains will probably be necessary. On the other hand, extremely flat topography may make it necessary to elevate the grade considerably above the surrounding land. The nature of the soil, the topography, and the rainfall must all be considered if a system of drainage is to be planned properly.

The second requirement, firmness, can be secured only after the road has been properly drained. Soils which readily absorb moisture can not be properly drained in wet weather and should not be permitted to form a part of the subgrade. In order that the subgrade may be unyielding, it is also necessary that the roadbed be thoroughly compacted. In forming embankments, the material should be put down in layers not over 8 inches thick, and each layer should be thoroughly rolled. In excavation care should be exercised, if the material is earth, not to permit plows or scrapers to penetrate below the subgrade. The subgrade in both excavation and embankment should be brought to its final shape by means of finish grading with picks and shovels and rolling.

When completed the subgrade should be uniform in grade and cross section, or otherwise the foundation must be made unnecessarily thick where depressions occur, in order that its grade and cross section may be uniform and its thickness not less at any point than that required. The subgrade should be repeatedly rolled and reshaped until the desired shape is secured. The curbs, which should be set before the final finishing, may be made to serve as a guide for this work.

The shoulders, while essentially a part of the road surface, should be constructed at the same time that the subgrade is formed. This is necessary in order that the curb may be properly supported while the pavement is being laid and rolled. The shoulders should never be less than 4 feet wide and should consist of some material which compacts readily under the roller and which does not readily absorb water. Not infrequently one of the shoulders is made sufficiently wide to form an earth roadway parallel to the brick pavement. Such an arrangement serves to relieve the pavement of considerable traffic during favorable seasons and thereby adds greatly to its life. The general method of constructing shoulders for brick roads is not essentially different from that employed for other types of pavements.

CURBING.

All brick pavements should be supplied with strong, durable curbing, both on the sides and at the ends. Otherwise, the marginal brick will soon become displaced by the action of traffic, and their displacement will of course expose the brick next adjoining, so that deterioration will soon spread over the entire pavement. Properly constructed curbing, on the other hand, will hold the pavement as in a frame and enable the brick to present their combined resistance to the destructive influences of traffic.

Satisfactory curbs may be constructed of stone, Portland cement concrete, or vitrified clay shapes made especially for this purpose. Wood has also been used for curbs to a limited extent, but when it is considered that the life of a brick pavement under ordinary conditions should far exceed the life of any wood curb which might be devised, the economy of employing a more durable material is readily apparent.

Stone curbing may be made from any hard tough stone which is sufficiently homogeneous and free from seams to admit being quarried into blocks not less than 4 feet long, 5 inches thick, and 18 inches deep. On account of their ordinarily homogeneous structure, granite and sandstone are probably more used for curbs than any other kind of stone.

All stone curbing should be hauled, distributed, and set before the subgrade is completed. The individual blocks should be not less than about 4 feet long except at closures, and should have a depth of from 18 to 36 inches, depending on traffic conditions and on whether the curb is to project above the surface forming one side of the gutter. The neat thickness need never be greater than 6 inches and, where the traffic conditions are not severe and the quality of the stone is good, a thickness of 4 inches will ordinarily prove satisfactory. Stone curb should always be set on a firm bed of

gravel, slag, or broken stone, not less than 3 inches thick, and should be provided with a backing of the same material on the shoulder or sidewalk side. Figure 1 shows a typical stone curb in place.

Where suitable stone is not readily available or when from any cause the cost of stone curbing would prove excessive, a curb constructed of Portland cement concrete may frequently be advantageously used. Concrete curbs may be constructed alone or in combination with either a concrete gutter or a concrete foundation. The advisability of constructing the curb in combination with the foundation, however, is doubtful. Very little is saved by such an arrangement, and the small saving is probably even more than offset by the additional difficulty involved in preparing the subgrade

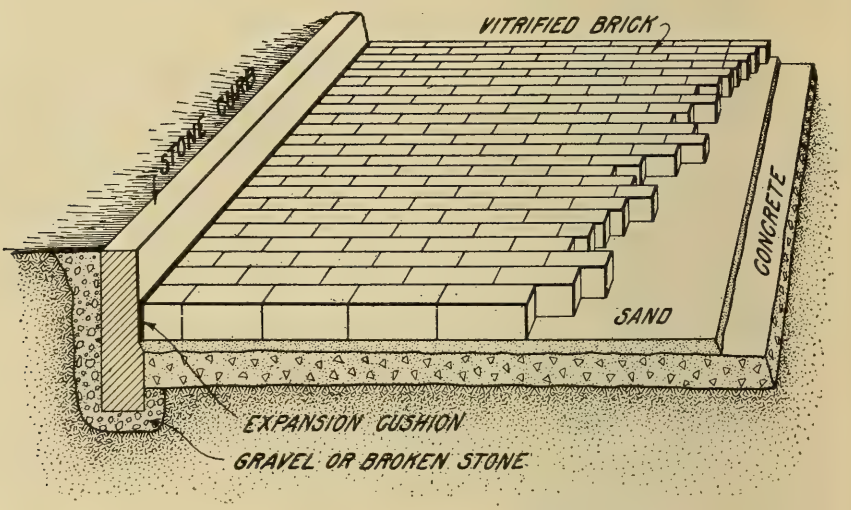


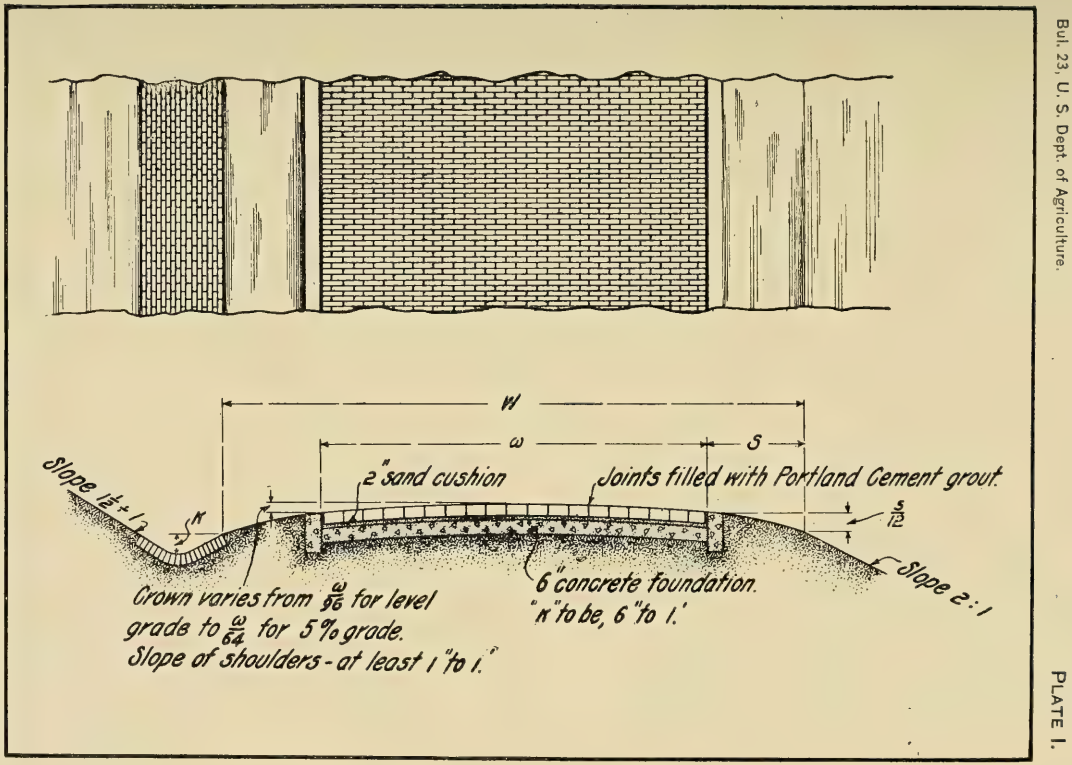
FIG. 1.—Proper method of constructing stone curb.

without the curb to serve as a guide. Concrete curbs should have approximately the same cross-sectional dimensions as stone curbs and should be constructed in sections not exceeding about 7 or 8 feet in length. Figures 2 and 3 and Plate I show the three common methods of constructing concrete curbs.

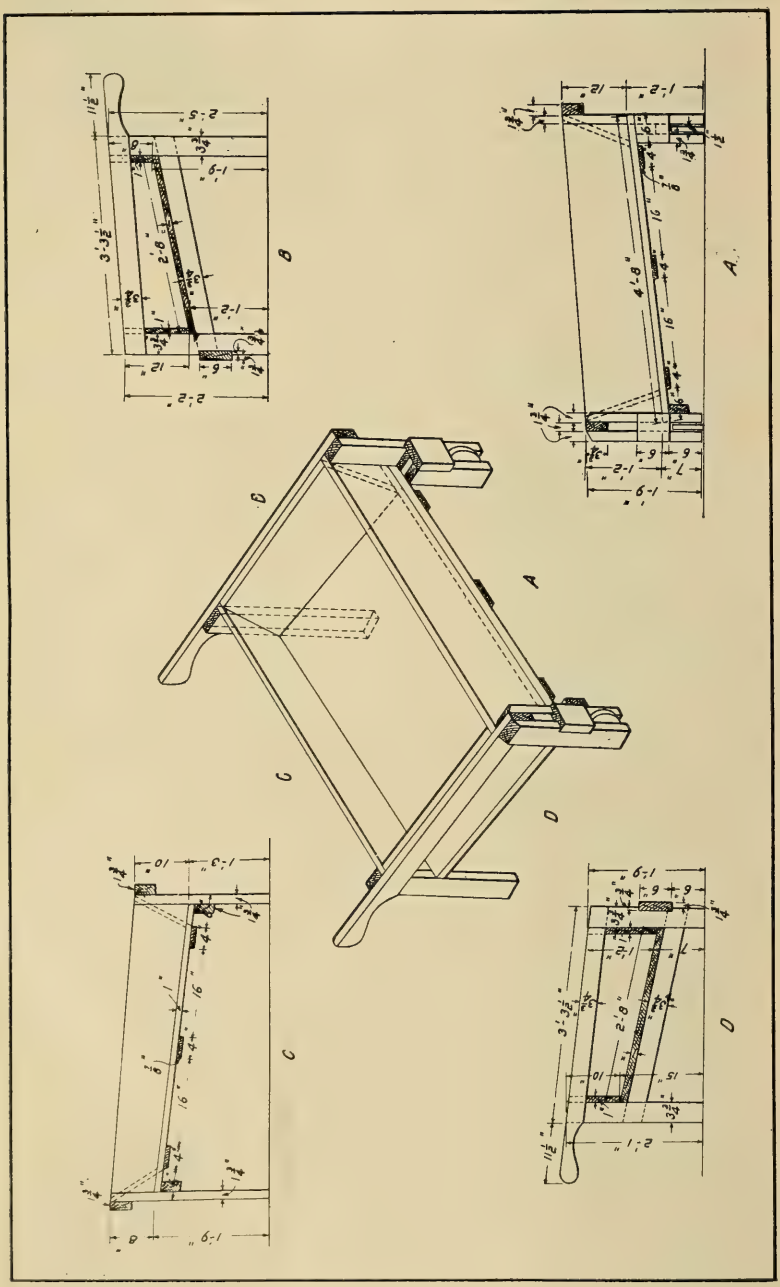
Vitrified clay curbing should be set in much the same manner as that described for stone curbing. The principal additional requirement is that, since vitrified clay is a lighter material than stone and the curb sections are ordinarily shorter, the bedding must be made correspondingly more secure in order to prevent displacement.

THE FOUNDATION.

A firm, unyielding foundation is one of the most essential features of a brick pavement. This fact can be more readily appreciated when it is considered that the surface of a brick pavement is made up



TYPICAL PLAN AND SECTION FOR BRICK ROAD.



PLAN FOR GROUT BOX HAVING LOW CORNER.

of small individual blocks, any one of which might be easily forced down, causing unevenness in the surface, if the foundation were poor; and since the ability of the pavement to resist wear depends very largely on the smoothness of the surface, every reasonable precaution should be taken to prevent any unevenness from developing.

The proper type of foundation depends largely on the material composing the subgrade and the character of traffic for which the road is designed. Where the traffic is comparatively light and the subgrade is composed of some firm material which does not readily absorb water, a very satisfactory foundation may be constructed of broken stone or gravel filled with sand. Where the traffic is comparatively heavy, however, or where the material composing the subgrade is defective in any way, a monolithic concrete foundation should be used. Foundations consisting of a course of brick laid flat upon a

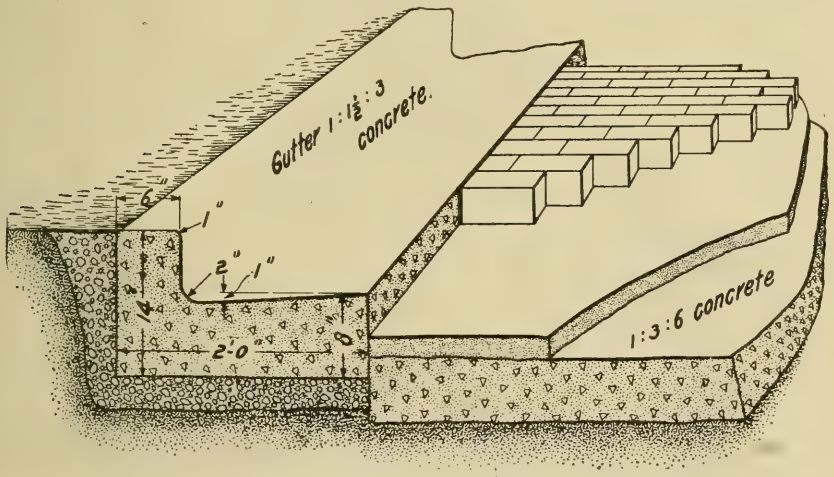


FIG. 2.—Concrete curb and gutter combined.

previously compacted layer of gravel or broken stone have also been extensively used, and pavements constructed upon foundations of this kind, ordinarily called "double-layer" pavements, have in general proved satisfactory, even where the subgrade was composed of an inferior material. At the present time, however, such foundations can rarely be constructed at less cost than the more durable concrete foundations, and they will therefore be given no further consideration here.

Gravel and broken-stone foundations may be spread in one or more courses, each of which should be from 5 to 9 inches thick before compacting. The materials used should conform in the matter of physical characteristics to the ordinary requirements for similar materials used in constructing macadam roads; that is, the stone or gravel should be clean, hard, tough, and durable, and should be graded in size between certain reasonable, fixed limits. It should be

uniformly spread on the road, either from dumping boards by means of shovels or from wagons especially designed to spread the material as it is being dumped. Where whole loads are dumped in one place and then spread out to the required depth, it is very difficult to obtain uniform density. Usually those spots where the loads are dumped are more densely compacted than the rest of the foundation, and this lack of uniformity very soon manifests itself by producing unevenness in the surface of the pavement. Broken-stone and gravel foundations should be compacted in the usual manner by rolling with a power roller weighing not less than about 10 tons, and sufficient clean, coarse sand to fill the voids should be spread and flushed

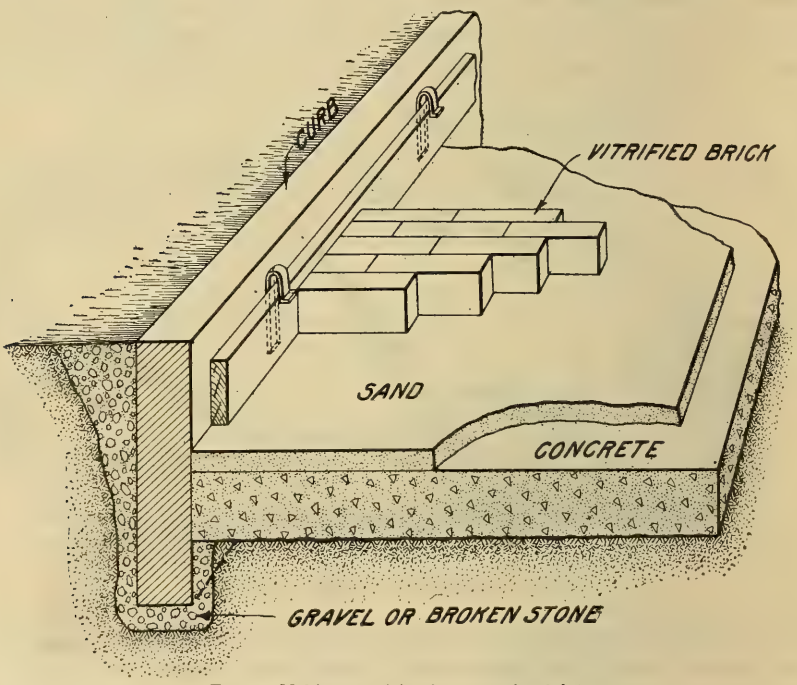


FIG. 3.—Making provision for expansion joint.

into the foundation while the rolling is in progress. When complete the foundation should present a surface uniform in grade and cross section and parallel to the proposed surface of the finished pavement.

Concrete foundations are unquestionably better adapted for brick pavements than any other type. They are practically monolithic in form, nearly impervious to water, and possess a relatively high crushing strength. All of these qualities may be obtained with a relatively "lean" concrete if the subgrade has been properly prepared. Under ordinary circumstances a satisfactory foundation may be constructed of concrete composed of 1 part of Portland cement, 3 parts of sand, and from 5 to 7 parts of broken stone or screened gravel.

The sand should be clean and well graded in size, and the stone or gravel should conform to the requirements given above in connection with the discussion of foundations constructed of those materials.

Foundations for brick pavements have also been constructed of timber boards laid on sand, and in some instances of sand alone. These foundations have seldom proved satisfactory for any great length of time, however, and can, therefore, be economically used only when the pavement is to be constructed of an inferior grade of brick.

SAND CUSHION.

Since it is practically impossible to construct an absolutely smooth foundation, and since there is always a slight variation in the size of paving brick, owing to slight differences in the amount of shrinkage at the time of burning, it is necessary to provide an adjustable cushion of some kind between the foundation and the brick for correcting these slight irregularities, in order to secure an even surface and a uniform bearing for the brick. Sand has been found a most satisfactory material of which to construct this cushion, and is almost exclusively used for this purpose. The proper thickness for the sand cushion will of course depend on the extent of the inequalities above mentioned. Two inches is the most usual thickness, however, and this thickness has generally proved very satisfactory.

The sand used in the cushion should be clean, free from pebbles, and preferably fine grained. If dirt or vegetable matter is present, it will soon be leached out and cause unevenness to develop in the pavement, while pebbles prevent the brick from securing a uniform bearing, and ultimately produce the same result. Fine sand adjusts itself to the shape of the brick more readily than coarse sand, and is, therefore, given preference. It is also important that the sand should be dry when spread, because a comparatively small amount of moisture increases the volume of fine sand considerably, and moisture when present is not, as a rule, uniformly distributed. Even if it were uniformly distributed at the start, some spots would dry out more rapidly than others while the spreading was under way, and a lack of uniformity would thus be produced in the cushion.

In forming the cushion the sand is uniformly spread over the foundation to a depth slightly in excess of that desired, and is then smoothed off by drawing over it a template shaped to conform with the cross section of the finished pavement. The length of the template is ordinarily made equal to the width of the pavement where this is less than about 25 feet, and equal to half the width for wider pavements. Timber guides may be laid in the same direction as the pavement for the template to slide on, or the curbs may be made to serve as guides where this is convenient.

After the cushion is spread and uniformly "struck off" with the template to a depth slightly in excess of that required, it should be

thoroughly compacted by rolling with a hand roller weighing from 300 to 400 pounds, and any depressions which form should be corrected. This is necessary in order to secure uniform density and to prevent unequal settlement of the surface.

HANDLING AND LAYING THE BRICK.

The brick may all be hauled and piled at convenient intervals along the sides of the roadway before grading is begun, or, if more convenient, they may be delivered as needed on the work. Hauling over the finished pavement with wagons until it is complete and opened to traffic should be avoided. If the brick are delivered on the work as needed, they should be unloaded from the wagons outside of the curb and carried to the pavers, either by hand or in wheelbarrows. Plank trackways should also be provided over the newly laid pavement for the wheelbarrows when they are used.

The brick should in all cases be uniformly piled by hand on the new pavement conveniently close for the pavers, and each brick should be so placed that the regular operation of picking it up and placing it in the pavement will bring the best edge up. This method of handling the brick requires somewhat more labor than the common method of dumping them from wheelbarrows, but it eliminates to a great extent the practice of picking out and turning over chipped or kiln-marked brick, after the pavement is laid. This is very objectionable on account of the disarrangement of the sand cushion, which is frequently occasioned.

The brick should be laid on edge and in uniform courses running at right angles to the line of the pavement, except at intersections; and in order to "break the joints" each alternate course should begin with a half brick. In laying the brick the pavers stand on the pavement already laid and, beginning at the curb each time, carry across as many courses together as they can conveniently reach. The courses should be kept straight and close together, and if necessary each block of eight or ten courses should be driven back by means of a sledge and a piece of straight timber approximately 2 by 4 inches by 5 or 6 feet long. The brick should also be laid close in the courses and should be crowded together, if necessary, after a course is laid, by means of a crowbar inserted at the curb.

After the brick are laid, the pavement should be carefully inspected for the purpose of detecting soft or otherwise defective brick. Misshapen or broken brick may be detected by the eye alone and the soft brick by sprinkling the pavement with water. The soft brick appear comparatively dry while the water is being applied and comparatively wet after the sprinkling is stopped. All defective brick should, of course, be replaced by others which meet the requirements of the specifications.

TRUING THE SURFACE.

After the pavement has been laid and all defective brick have been replaced to the satisfaction of the engineer, the next step is to sweep the surface clean and smooth out all inequalities by means of ramming or rolling. The rolling should be done with a power roller weighing from 3 to 5 tons, and the pavement should ordinarily be rolled in both the longitudinal and transverse directions. The longitudinal rolling should be done first and should begin at the curbs and progress toward the crown. The roller should pass at least twice over every part of the pavement in both transverse and longitudinal directions. In order to neutralize any tendency which the brick may have to careen under the roller, the number of forward trips over any part of the pavement, if more than two trips are required, should equal the number of trips backward over the same part.

In places where it is impracticable to use the roller for truing the surface, such, for example, as along the curbs or concrete gutters or around manholes, the brick should be brought to a true surface by means of ramming. For this purpose a wooden rammer loaded with lead and weighing from 80 to 100 pounds may be used. The blows of the rammer should not fall directly upon the brick, but should be transmitted through a 2-inch board laid parallel to the curb.

After the pavement has been trued up, as described above, it should be inspected again for broken or otherwise damaged brick, and also for those which have settled excessively, owing to some lack of uniformity in the sand cushion. All defects should be corrected and the areas distributed in making the corrections should be brought to a true surface by tamping.

FILLING THE JOINTS.

In order to keep the brick in proper position and protect the edges from chipping, it is necessary to fill the joints with some suitable material before the road is opened to traffic. The materials which have in the past been most commonly used for this purpose are sand, various bituminous preparations, and a grout made of equal parts of Portland cement and fine sand mixed with water.

Sand is the least expensive of these materials, but there are several very serious objections to its use as a joint filler: (1) It does not protect the edges of the brick; (2) it is easily disturbed in cleaning the pavement and is likely to be washed out by rain on steep grades; (3) it does not entirely prevent water from penetrating through to the foundation; and (4) it does not bond the individual brick together, and so enable them to present a concerted resistance to traffic.

The bituminous fillers vary considerably in quality and efficiency, but all are more or less unsatisfactory. One of the principal objections to their use is based on their tendency to run out of the joints into the gutters during warm weather and to crack and spall out

during cold weather. This tendency can, of course, be partially overcome by exercising proper care in selecting the materials. It should also be noted in their favor that brick pavements, the joints of which have been filled with bituminous preparations, are ordinarily less noisy at first than those in which a Portland cement grout filler has been used. The grout filler is unquestionably very much superior from a standpoint of durability, however, and the excessive noise under traffic which has been frequently observed in connection with its use can be largely eliminated by the use of proper bituminous expansion cushions along the curbs. It is, therefore, recommended as better adapted for filling the joints in brick pavements than any other material which has been commonly used for that purpose.

When the joints of a brick pavement are properly filled with Portland cement grout the individual brick are firmly bonded together and the pavement is thereby practically converted into a monolith. Moreover, since the material composing the joints scarcely wears more rapidly than the brick, the edges of the brick are well protected, and the importance of this feature has already been pointed out.

The most satisfactory method yet devised for mixing and applying the grout filler may be described as follows: Grout boxes constructed in such manner that, when resting on a level platform, one corner will be lower than the others should first be provided. A suitable design for such boxes is shown in Plate II. The number of boxes required depends on the width of the pavement; ordinarily one box to each 10 feet of width will be found sufficient. The grout, which should be put on in two applications, is prepared in batches each of which consists of a quantity of cement not exceeding one sack, a like amount of fine, clean sand, and water. The sand and cement should first be thoroughly mixed dry and sufficient water then admixed to produce a liquid mixture. The consistency of the mixture for the first application should be approximately the same as that of thin cream, and for the second application it should be somewhat thicker.

The pavement should be cleaned and thoroughly sprinkled as a preliminary to making the first application of grout, and it should be kept moist by gentle sprinkling while this application is being made. The grout should be removed from the boxes and spread upon the pavement by means of scoop shovels, and it should be immediately swept into the joints. For this purpose a coarse rattan or fiber push broom should be used in the first application, and a squeegee in the second application. The squeegee is made by clamping a piece of four-ply rubber belting or some other similar material, about 6 by 20 inches in size, between two pieces of board and attaching a suitable handle. The grout in the boxes should be continually stirred until the last shovelful is removed, otherwise a separation of the sand and cement will almost certainly occur.

The first application should proceed about 50 feet in advance of the second. Usually both applications are made by the same crew of laborers. They simply turn back after having covered the allowable distance with the first application and, mixing the grout in the same boxes, bring up the second application. The second application of grout should completely fill the joints flush with the top of the brick.

After the joints are filled as described above and the grout has taken its initial set, the entire surface should be covered to a depth of approximately one-half inch with clean sand. This is done to protect the pavement from the weather and to keep it in a moist condition while the grout is hardening. If necessary, in order to keep the sand moist, it should be occasionally sprinkled for several days after it is spread.

The sand covering should be permitted to remain on the surface for at least 10 days, and during this period the pavement should be kept entirely closed to traffic. If the weather is unfavorable, the length of time during which traffic is kept off the road should be increased.

EXPANSION CUSHIONS.

It has been customary in the past to provide both longitudinal and transverse bituminous expansion cushions in grout-filled brick pavements, but recent practice has demonstrated that the transverse cushions may be advantageously omitted if proper longitudinal cushions are provided. The principal objection to the use of transverse expansion cushions is based on the fact that the material composing the cushions frequently softens during warm weather and runs out toward the curb, thus leaving the edges of the adjoining brick exposed to destructive impact from the wheels of passing vehicles. Even if the cushion consisted of a material which does not run in warm weather, it is necessarily softer than the brick, and the natural result is still the development of unevenness in its immediate vicinity. No such objection can exist concerning longitudinal expansion cushions, however, if they are placed adjacent to the curbs and constructed of proper material. They not only furnish a means for the pavement to expand and contract with changes in temperature but they also eliminate to a large extent the disagreeable rumbling which has been so frequently associated with grout-filled brick pavements.

The bituminous material of which the expansion cushions are made should be such as to remain firm in summer and not to become brittle in winter. It should also possess the quality of durability. In order to insure that any given material is suited for such a purpose, it is usually considered necessary to prescribe certain laboratory requirements to which it must conform, and examples of these, which have

been found to give good results, are contained in the section entitled "Typical specifications." (Cf. p. 21 et seq.)

Expansion cushions should be provided for at the time the brick are laid, by placing a board of the required thickness on edge adjacent to each curb, as shown in figure 3. Small iron wedges, such as are shown in this figure, may be inserted between the curb and the board at the time the board is set. These wedges may be readily loosened and removed after the bricks have been laid and grouted, and may consequently be made to facilitate the removal of the board.

The proper thickness for expansion cushions is a matter concerning which much difference of opinion exists among highway engineers. Some engineers advocate a minimum thickness of 1 inch, while others claim to have secured their best results by using expansion cushions having a minimum thickness as low as three-eighths inch for very narrow pavements. It is generally agreed, however, that the thickness of the cushion should vary with the width of the pavement. The following suggestions for proportioning the cushion are offered as being fairly representative of the best practice.

TABLE 1.—*Ratio of thickness of cushions to width of roadway.*

Width of roadway (feet).	Thickness of cushion (inches).
20 or less	½
20 to 30	⅝
30 to 40	1
Over 40	1¼

Plates III to VII, and Plate VIII, figure 1, show the various steps in the construction of a brick pavement. Plate VIII, figure 2, and Plate IX, figure 1, show the finished pavement as it should appear, and Plate IX, figure 2, shows the advantage possessed by grout-filled joints over joints filled with a soft material.

COST OF BRICK PAVEMENTS.

The cost of brick pavements varies widely, and is affected by so many influences that it is difficult to attempt to derive a general expression showing the relation between probable cost and local conditions. The prices of brick, as also the prices of the various materials entering into the foundation, vary greatly according to the locality and the freight rate. The cost and efficiency of labor is also far from being constant. Furthermore, the material composing the subgrade and the method of preparing it may exert a marked influence on the cost of the pavement. The following statements regarding cost, then, must be considered as representing average conditions, and

FIG. 1.—FINE GRADING.

FIG. 2.—ROLLING.

PREPARING THE SUBGRADE FOR A BRICK ROAD.

Fig. 1.—Mixing Concrete for the Foundation.

Fig. 2.—Finished Concrete Foundation.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

FIG. 1.—SPREADING SAND CUSHION.

FIG. 2.—ROLLING SAND CUSHION.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

FIG. 1.—LAYING THE BRICK.

FIG. 2.—ROLLING THE PAVEMENT.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

FIG. 1.—FILLING THE JOINTS, FIRST COAT.

FIG. 2.—FILLING THE JOINTS, SECOND COAT.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

FIG. 1.—FINISHED BRICK PAVEMENT PROTECTED BY SAND COVERING.

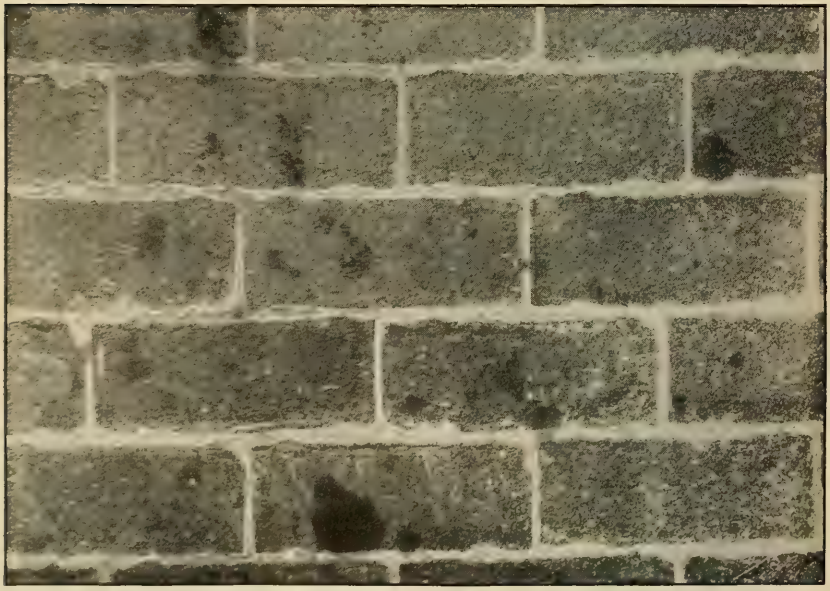


FIG. 2.—SHOWING PROPERLY FILLED GROUT JOINTS.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

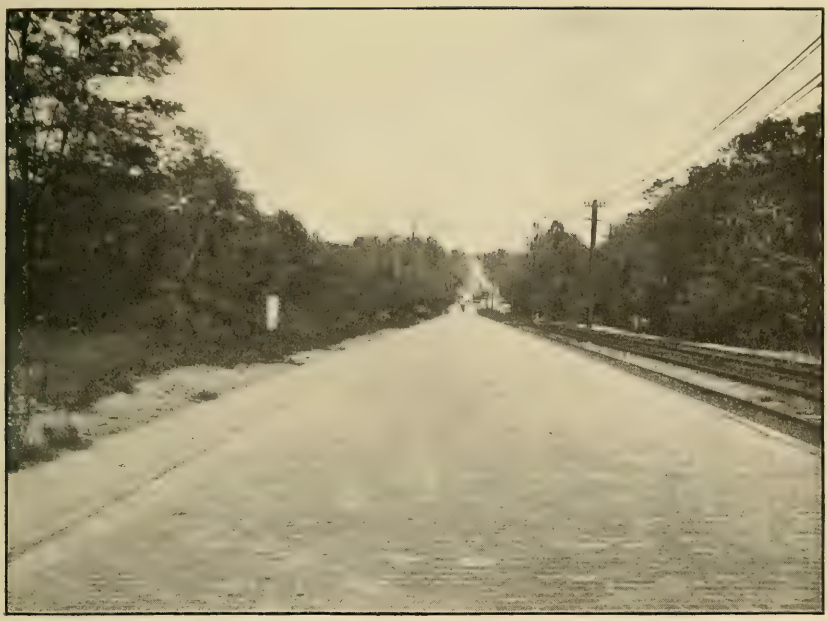


FIG. 1.—EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

Finished pavement in service.

FIG. 2.—GROUT-FILLED BRICK PAVEMENT, HAVING LONGITUDINAL JOINTS IN CENTER AND OCCASIONAL TRANSVERSE JOINTS FILLED WITH SOFT FILLER.

Unsightly appearance at right caused by widening roadway.

care must be exercised in applying them to special cases. They are intended as a guide in preparing estimates of probable cost.

The grading is usually paid for by the cubic yard, and the cost, of course, varies with the character of the soil and the necessary amount of excavation. In light, easily loosened soils, grading may usually be done at from 25 to 40 cents per cubic yard. In hard earth containing more or less loose rock, the cost per cubic yard generally runs from 40 to 75 cents, while grading in solid rock may sometimes cost as much as $1.50 per cubic yard. The cost of the rough grading should be considered entirely apart from the cost of the pavement.

The cost of shaping and rolling the subgrade after the rough grading is completed will ordinarily vary from 3 to 5 cents per square yard. This cost should be included with the other items which make up the cost of the pavement.

The cost of the curbs varies with the character of the material used. Stone curbs ordinarily cost from 25 to 75 cents per linear foot, while curbs made of Portland cement concrete cost, as a rule, from 20 to 50 cents per linear foot. The higher prices for the concrete curbs apply principally to special cases requiring extra form work or considerable extra material.

The cost of the foundation depends largely on the cost of the materials with which it is constructed. Gravel or broken stone can usually be spread and rolled at from 5 to 7 cents per square yard, while the cost of these materials, delivered, varies from $0.60 to $2 per cubic yard. Mixing and placing concrete usually costs from 35 to 75 cents per cubic yard, according to the amount of work to be done and the methods employed, and the cost of the materials, delivered, ordinarily varies from $2.50 to $4.50 per cubic yard of concrete.

The cost of paving brick at the kiln varies from about $12 to $14 per thousand. Estimating 45 brick to the square yard, each 1,000 brick cover approximately 22 square yards, which makes the cost at the kiln per square yard of pavement vary from 55 cents to about 65 cents. These figures mean very little, however, unless the kiln is located conveniently near where the brick are to be used, for freight charges not infrequently amount to more than the cost of the brick.

A force consisting of one paver and five laborers should place on an average about 220 square yards of brick per 10-hour day; while supervision, rolling, and incidental expenses are ordinarily equivalent to the cost of hiring about three and one-half additional laborers.

If C = cost of cement per barrel, S = cost of sand per cubic yard, A = cost of coarse aggregate per cubic yard, B = cost of paving brick per 1,000, and L = cost of labor per hour, with all materials considered delivered on the work and all costs expressed in cents, then the probable cost of constructing a brick pavement, including the

subgrade, a 6-inch concrete foundation, and suitable curbs, may be estimated by substituting in the formula:

$$\text{Cost per square yard} = 1.90\ L + .213\ C + .138\ S + .157\ A + .045\ B.$$

The cost as estimated from this formula should, however, be increased by about 10 per cent to allow for wear on tools and machinery and to guard against unforeseen contingencies. If it is desired to use a different thickness of foundation, it is safe to assume that each inch subtracted or added to the thickness of the foundation will make a corresponding difference of from 8 to 12 cents in the cost per square yard.

MAINTENANCE OF BRICK PAVEMENTS.

If brick pavements are properly constructed at the start, the work of maintaining them is very slight. Under the closest inspection, however, some inferior material is likely to become incorporated either in the foundation or in the surface, and it is, therefore, very important that a brick pavement be very carefully watched for the first few years of its life to see that no unevenness develops either because of defective bricks having been used in the surface or because of insufficient support from the foundation at any point. Whenever any unevenness develops, it should be immediately rectified. Otherwise the pavement will become irregularly worn in the vicinity of the defects and expensive repairs will eventually be necessary.

Not infrequently weak spots develop in broken stone or gravel foundations, owing to surface water finding its way through joints in the pavement which have not been properly filled with grout. Careful observation of the joints should, therefore, constitute a part of the early maintenance work, and any defective joints discovered should be immediately remedied. Where the foundation is constructed of concrete, however, slight defects in the joints seldom result in any very serious damage.

If care is exercised to correct all defects which appear within the first few years of the life of a well-constructed brick pavement, the work of maintaining the pavement proper should thereafter, except for cleaning, be almost negligible. The shoulders and drainage structures, of course, need occasional attention, just as in the case of any other pavement, but if they are properly constructed at the start repairs will usually be very slight.

The life of a well-constructed brick pavement can not be estimated with any great degree of exactness, first, because the traffic conditions are constantly changing, and, second, because no brick pavement which has been constructed in accordance with the best modern practice has yet worn out. The amounts of wear sustained by given pavements during comparatively long periods of years have been

determined in several instances, but have usually been so small as to make the probable terms of service appear almost indefinite. It is evident, however, that in order to secure the full benefit of this excellent resistance to wear the surface of the pavement must not be permitted to become uneven because of the failure of isolated bricks.

TYPICAL SPECIFICATIONS FOR THE CONSTRUCTION OF BRICK ROADS.

Engineer.—The term "engineer," as hereinafter employed, shall be understood to mean the engineer authorized by the officials legally responsible for the proposed improvement. The engineer will furnish all lines and grades, set all necessary stakes, and furnish estimates of the work done upon which to base both partial and final payments. All instructions necessary to give effect to any part of these specifications will be furnished by the engineer, and his decision concerning all matters herein left to his judgment shall be final and conclusive.

Plans and drawings.—All plans and drawings furnished by the engineer which show the general location, profile, details, and dimensions of the proposed road are hereby made a part of these specifications, and the work shall in all respects conform to these plans and drawings, except that such modifications as in the judgment of the engineer are made necessary by the exigencies of construction may be made from time to time. On all drawings figured dimensions are to govern in cases of discrepancy between scale and figures.

Grading and subgrade.—All rubbish, stumps, trees, and other encumbrances which occur on the line of the work shall be removed by the contractor at his own expense.

The roadbed shall be graded to conform to the lines, cross sections, and grades furnished by the engineer. Embankments shall be constructed of a good quality of soil or other material satisfactory to the engineer. They shall be built up in layers not exceeding 12 inches in thickness, and each layer shall be thoroughly compacted by means of a roller weighing not less than 10 tons, or by some other means which the engineer has previously approved.

All soft, spongy, or otherwise objectionable material encountered in preparing the subgrade shall be removed and replaced by other material satisfactory to the engineer. In excavating the contractor shall exercise care not to disturb any material lying beneath the subgrade, as shown on the drawings furnished by the engineer, except in removing objectionable material as above provided.

The entire subgrade shall be rolled with a roller weighing not less than 10 tons, and when complete shall be firm and hard. It shall conform in cross section to the proposed surface of the finished roadway and be at the required depth below it.

Stone curbing.—All stone curbing shall have the shape and size shown on the plans, and shall be hauled and set before the subgrade is completed. The stone used shall be hard, tough, and of a homogeneous texture, and no section of curbing shall have a length less than 4 feet. Stone curbing shall be set true to line and grade, and shall be securely bedded in either broken stone or gravel.

Concrete curbing.—All concrete curbing shall be constructed before the subgrade is completed. It shall have the cross section shown on the plans, and shall be composed of Portland cement concrete, mixed in the proportion 1 part of cement, 2 parts of sand, 4 parts of broken stone or washed gravel, and sufficient water to make a quaky mixture. The specifications as to quality of the materials, mixing and placing the concrete, etc., hereinafter given under "Concrete foundation," shall apply also to concrete curbs.

Forms for concrete curbs shall be constructed of dressed lumber, and the curb shall be constructed in sections not less than 4 feet nor exceeding 12 feet in length. When complete the curb shall present a smooth, neat, uniform appearance, and shall be true to line and grade.

Marginal curb.—Marginal curbs shall be constructed at the ends of the pavement and at all intersections with other roads and driveways. The marginal curbs shall conform to the specifications given above for the kind of curbing employed, except that they shall be shaped to conform to the cross section of the pavement.

Broken stone or gravel foundation.—If a broken stone or gravel foundation is called for, it shall be constructed of sound, durable material, and to the compacted depth shown on the plans. The material shall be well graded in size between that which will just be retained on a screen having $\frac{1}{4}$-inch circular openings and that which will just pass a screen having $1\frac{1}{2}$-inch circular openings. After the broken stone or gravel has been spread, sufficient clean sand or stone screenings to fill the voids shall be spread over it and flushed in by means of sprinkling and rolling. When completed the foundation shall be well compacted, free from depressions, and uniform in grade and cross section.

Concrete foundation.—If a concrete foundation is called for, it shall be constructed to the depth shown on the plans in the following manner:

The subgrade shall be completed for a distance of at least 50 feet in advance of the foundation work. The foundation shall be constructed of Portland cement concrete mixed in the proportions 1 part of Portland cement, 3 parts of sand, 6 parts of broken stone, and sufficient water to bring the mass to a condition commonly described as quaky. The concrete shall be thoroughly mixed to the satisfaction of the engineer, either by hand or in a mechanical mixer approved

by the engineer, and the materials composing it shall conform to the following requirements:

Cement.—The cement shall be of some standard brand, and shall conform to the United States Government specifications for Portland cement, as contained in Circular 33 of the Bureau of Standards. Cement shall be delivered in sacks of 94 pounds net weight, and each sack shall be considered as having a volume of 1 cubic foot. All sacks which contain lumps or the contents of which have been damaged by exposure to the weather or other cause shall be rejected.

Sand.—The sand shall consist of dry clean quartz grains, and shall not contain more than 5 per cent of clay, loam, or other foreign materials. The grains shall be well graded and of such size that all will pass a ¼-inch mesh screen and not more than 20 per cent will pass a No. 50 sieve.

Coarse aggregate.—The coarse aggregate may consist of either broken stone or gravel. Stone shall be hard and tough, and shall be broken in such manner that all will be retained on a ¼-inch mesh screen and will pass a 1½-inch mesh screen. Not more than 75 per cent of the stone shall pass a ¾-inch mesh screen, and not more than 75 per cent shall be retained on such a screen.

Gravel shall consist of hard, sound particles of stone, thoroughly clean, and shall conform in size to the above specifications for broken stone.

Placing.—The concrete shall be deposited in place immediately after it is mixed and shall be thoroughly compacted as fast as it is placed. The top surface shall be smoothed by troweling with spades or by some other means approved by the engineer, and when completed shall conform to the proposed surface of the finished pavement at the required depth below it.

Time of setting.—The concrete shall be carefully protected from the weather and all other disturbing influences, and kept moist by sprinkling for at least 36 hours after it is placed in the foundation. This period may be increased at the discretion of the engineer. Any damage resulting to the foundation before the wearing surface has been laid, no matter what the cause of such damage may be, shall be repaired by the contractor at his own expense.

Sand cushion.—After the foundation has been constructed and permitted to set as above provided, a layer of sand shall be uniformly spread over the foundation to such depth that when "struck off" and compacted its thickness shall be 2 inches. The sand composing this layer shall be dry when spread and shall conform in all respects to the requirements given above for the sand to be used in concrete. The cushion shall be struck off with a suitable template which conforms to the cross section of the finished pavement, and shall be thoroughly compacted by rolling with a hand roller weighing not less

than 300 pounds. When finished it shall present a smooth, uniform appearance.

The brick.—The brick shall be delivered upon the road and neatly piled outside of the curb lines at such points as are approved by the engineer before the grading is started. The loading, hauling, and unloading shall be carefully done, and at no time shall the brick be thrown, dumped, or in any way roughly handled.

All brick used in the pavement shall be thoroughly vitrified, regular in shape and size, evenly burned, and first class in all other respects. The dimensions shall be 3½ inches in width, 4 inches in depth, and 8½ inches in length, and any brick varying from these dimensions by more than one-half inch in length or by more than one-eighth inch in width or depth shall be rejected. If the edges are rounded, the radius of the curve shall not exceed one-eighth inch. Each brick shall have projections on one side, formed during the process of manufacture, which will serve to produce joints not exceeding one-fourth inch in width and not less than one-eighth inch, when the brick are placed in the pavement.

No brick shall be used in which representative specimens, when subjected to the rattler test recommended by the subcommittee on paving brick of the American Society for Testing Materials [1] lose more than 22 per cent of the original weight of the dried brick composing the charge. In making this test 10 representative bricks shall constitute a charge and, in weighing the rattled brick, no part of a brick weighing less than 1 pound shall be included.

The modulus of rupture for any one representative brick shall not be less than 2,400, and the average modulus of rupture for all bricks tested shall not be less than 2,600. If this test is employed, at least five bricks shall be tested.

Any carload of brick more than 10 per cent of which fails to conform to any of the above requirements shall be rejected. If not more than 10 per cent of a carload fails to meet the requirements, the defective bricks may be picked out and the remainder of the carload used.

Laying the brick.—The brick shall preferably be carried to the pavers on pallets or in clamps and not wheeled in barrows. They shall be laid in straight courses at right angles to the line of the pavement, and if a variation in alignment of more than one one-hundred-and-twentieth the width of the pavement occurs, it shall be corrected by taking up and relaying affected courses.

No parts of brick shall be employed in the pavement except at the beginning and ending of the courses or at other closures. All brick shall be laid with the best edge exposed and as close as possible. After the brick are laid, they shall be carefully inspected and all those

[1] The complete specifications for making this test are given as an appendix to this bulletin.

which are soft, badly spalled, misshapen, or otherwise defective shall be removed and replaced with perfect brick. Kiln-marked brick may be turned over, and if the reverse edge is smooth and no other fault is found, they may remain in the pavement.

The above provision for correcting defects shall not be understood to relieve the contractor from exercising every reasonable precaution to see that only satisfactory brick are correctly placed in the pavement when it is first laid.

After the brick have been laid and inspected as above provided, they shall be brought to a true surface by means of rolling and tamping. The rolling shall be done with a power roller weighing not less than 3 tons nor more than 5 tons and the pavement shall be rolled in both longitudinal and transverse directions. The longitudinal rolling shall begin at the curbs and progress toward the center. The roller shall in all cases cover exactly the same area in making its backward trip which was covered in its forward trip, and shall proceed at a very slow rate until the entire pavement has received the first rolling. The longitudinal rolling shall continue until the brick have been brought to a true surface and are firmly embedded in the sand cushion. The pavement shall then be thoroughly rolled transversely at an angle of 45 degrees with the curb in both directions. Careful inspections shall be made after both the longitudinal and transverse rollings, and all broken or otherwise injured brick shall be removed and replaced to the satisfaction of the engineer.

The brick next to the curb and at other points not readily accessible to the roller shall be brought to a true surface by means of ramming with a hand rammer made of wood and loaded to weigh not less than 80 pounds. The blows of the rammer shall be transmitted through a 2-inch board not less than 5 feet long.

Filling the joints.—The filler shall consist of a grout composed of equal parts of Portland cement and sand, and shall be applied in two coats. The cement shall conform to the specifications hereinbefore given for Portland cement. The sand shall also conform to the specification contained herein for sand to be used in concrete, except that the largest grains shall be required to pass a $\frac{1}{8}$-inch mesh screen instead of a $\frac{1}{4}$-inch mesh screen.

The grout shall be mixed in small batches and not more than one sack of cement to one batch shall be mixed at any one time. The sand and cement shall be thoroughly mixed dry until the mass assumes an even shade of color. Sufficient clean water shall then be admixed to produce a consistency about equal to that of thin cream for the first application, and slightly thicker for the second application. The materials shall be mixed in suitable boxes, which have been approved by the engineer. The legs of each box shall have different lengths, so that the mixture will readily flow to the lowest corner of

the box, which shall be about 6 inches above the pavement. The grout shall be constantly stirred in the boxes until the last of it has been removed and applied to the pavement.

The grout for both applications shall be removed from the boxes and spread over the pavement by means of scoop shovels, and shall be immediately swept into the joints, with a coarse rattan or fiber push broom in the first application and with a squeegee or rubber broom in the second application. The pavement shall have been thoroughly sprinkled before the first application of grout is made and shall be kept moist by means of gentle sprinkling until the grout is spread.

Unless some other arrangement is approved by the engineer, both applications of grout shall be made by the same crew of laborers and with the same appliances. After the first application has advanced about 50 or 60 feet, the second application shall be made. When the second application has been finished, the grout shall entirely fill the joints and shall appear smooth and flush with the surface of the brick.

After the joints have been filled as above provided and the grout has taken its initial set the entire surface of the pavement shall be covered with a $\frac{1}{2}$-inch layer of sand. This sand layer shall be kept moist by sprinkling for at least 3 days and shall remain on the pavement for at least 10 days, and during this period the street shall be entirely closed to traffic. Any damage resulting from traffic or any other disturbing influence which has been prematurely permitted upon the pavement shall be repaired by the contractor at his own expense.

Expansion cushion.—An expansion cushion of the thickness indicated on the plans shall be constructed along each curb as follows:

Suitable provision for the cushions shall be made at the time the brick are laid by setting boards of the proper thickness on edge in the correct position along the curb. After the brick have been laid, rolled, and grouted and the grout has been permitted to harden, the boards shall be removed and the spaces which they occupied shall be filled with either coal-tar pitch or blown-oil asphalt.

If pitch is used, it shall be of such character as to adhere firmly to the paving brick and to the curb and shall be sufficiently plastic to allow for contraction and expansion in the pavement without developing cracks in the joints. It shall contain not less than 25 per cent and not more than 40 per cent of free carbon and shall not contain more than 0.5 per cent of inorganic matter. When tested by the cube method, its melting point shall be not less than 55° C. and not greater than 60° C.

If oil asphalt is used, it shall be soluble in chemically pure carbon disulphide to at least 99 per cent, and when tested by the cube

method its melting point shall be not less than 90° C. and not greater than 110° C. The penetration at 0° C. of a No. 2 needle acting one minute under a weight of 200 grams shall be not less than 2 millimeters. The penetration at 46° C. of a No. 2 needle acting five seconds under a weight of 50 grams shall not exceed 10 millimeters.[1]

When grouting, care shall be exercised to prevent the grout from covering and setting up over this cushion.

CONCLUSION.

Before concluding this discussion of brick pavements, it would seem desirable to emphasize the importance of proper engineering supervision. In the past many communities have expended large sums in efforts to improve their public highways without first having secured the services of some one competent to plan and direct the work. The results have usually been very unsatisfactory under such circumstances and have frequently served to discourage further effort. One of the mistakes most commonly observed consists in constructing some expensive type of pavement on a road where the location is faulty or the grades are impracticable. Not infrequently sharp angles in the alignment or abrupt changes in the grade, which might be easily and inexpensively remedied by an experienced engineer, are left to impede traffic throughout the life of a costly and perhaps durable pavement.

Even in constructing common earth roads it is doubtful economy to dispense with the services of a competent engineer, and if any considerable quantity of work is to be done, such services should certainly be secured. Since brick pavements are probably more expensive to construct than any other type of pavement at present used for country roads, it is all the more important that their construction should be carefully planned and well executed.

[1] Instead of making a poured joint, as above described, the cushion may be constructed of some of the specially prepared expansion-joint materials. These consist of thin, flexible boards, built up by successive layers of felt and a soft bituminous material. They can be obtained with a width approximately the depth of a brick, and a sufficient number of them to make the proper thickness of cushion are set on edge along the curb when the brick are laid.

APPENDIX.

METHOD FOR INSPECTING AND TESTING PAVING BRICK.[1]

The quality and acceptability of paving brick, in the absence of other special tests mutually agreed upon in advance by the seller on the one side and the buyer on the other side, shall be determined by the following procedure, viz:

(1) *The rattler test*, for the purpose of determining whether the material as a whole possesses to a sufficient degree, strength, toughness, and hardness;

(2) *Visual inspection*, for the purpose of determining whether the physical properties of the material as to dimensions, accuracy and uniformity of shape and color are in general satisfactory, and for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

The acceptance of paving bricks as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

SECTION I.—THE RATTLER TEST.

THE SELECTION OF SAMPLES FOR TEST.

ITEM 1. *Place of sampling.*—In general where a shipment of bricks involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, or on cars at their destination or on the street, when delivered ready for use. When the quantity under consideration exceeds 100,000, the sampling shall be done at the factory prior to shipment. Bricks accepted as the result of tests prior to shipment shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Section II (Visual inspection).

ITEM 2. *Method of selecting samples.*—In general the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be rejected by visual inspection as provided in Section II, except that where controversy arises, whole tests may be selected to determine the admissibility of certain types or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

ITEM 3. *Number of samples per lot.*—In general one sample of ten bricks shall be tested for every 10,000 bricks contained in the lot under consideration, but where the total quantity exceeds 100,000, the number of tests tested may be fewer than one per 10,000, provided that they shall be distributed as uniformly as practicable over the entire lot.

ITEM 4. *Shipment of samples.*—Samples which must be transported long distances by freight or express must be carefully put up in packages holding not more than 12 bricks each. When more than six bricks are shipped in one package, it must be so arranged as to carry two parallel rows of bricks side by side, and these rows must be separated by a partition. In event of some of the bricks being cracked or broken in transit, the sample shall be disqualified if there are not remaining ten sound undamaged bricks.

[1] Recommended by subcommittee on paving brick of the American Society for Testing Materials.

ITEM 5. *Storage and care of samples.*—Samples must be carefully handled to avoid breakage or injury. They must be kept dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100° Fahrenheit before testing.

THE CONSTRUCTION OF THE RATTLER.

ITEM 6. The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of materials and dimensions, and shall consist of barrel, frame and driving mechanism as herein described. Accompanying these specifications is a complete drawing (Pl. X) of a rattler which will meet the requirements, and to which reference should be made.

ITEM 7. *The barrel.*—The barrel of the machine shall be made up of the heads and headliners, and staves and stave-liners.

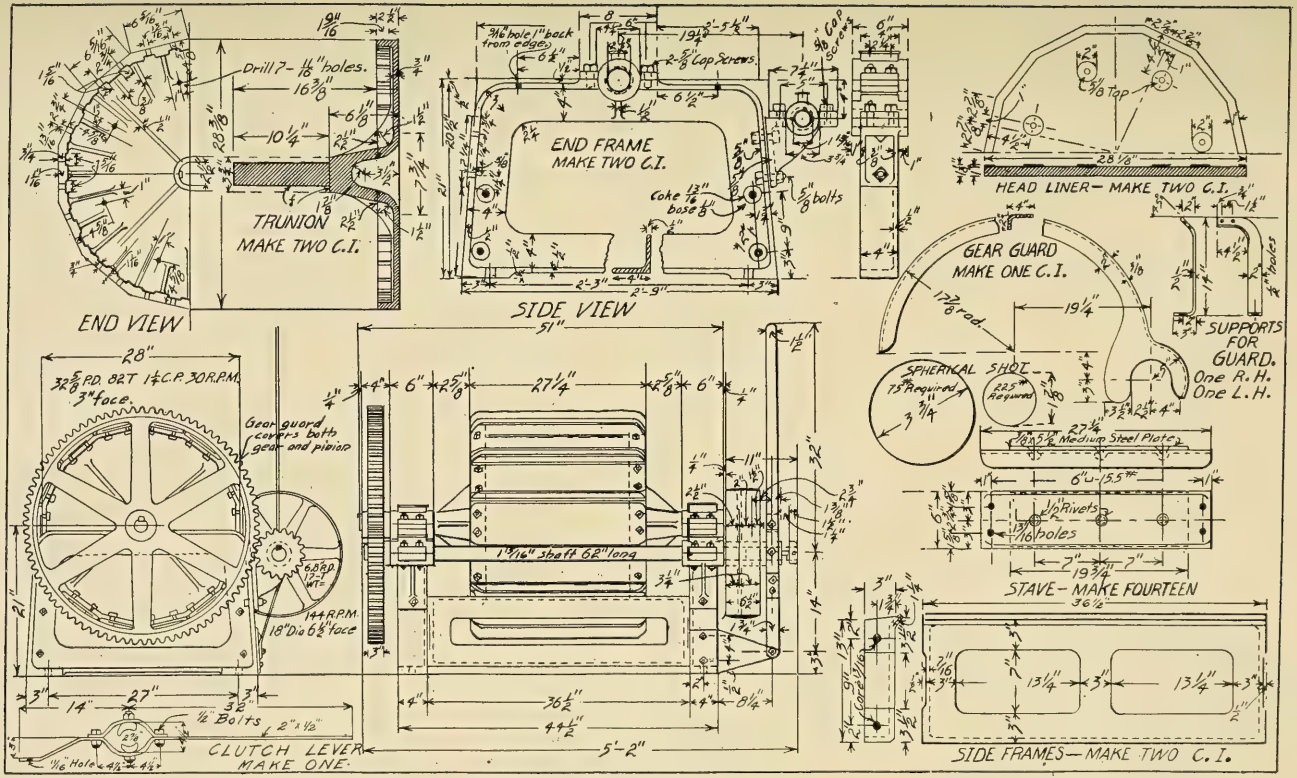
The heads may be cast in one piece with the trunnions, which shall be $2\frac{1}{2}$ inches in diameter, and shall have a bearing 6 inches in length, or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$-inch shafts, and shall be keyseated for two keys, each $\frac{1}{2}$ inch by $\frac{3}{8}$ inch and spaced 90 degrees apart. The shaft shall be a snug fit and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ inches in the head for the driving end of the rattler, and $11\frac{3}{8}$ inches long for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ inches.

The heads shall be not less than $\frac{3}{4}$ inch nor more than $\frac{7}{8}$ inch thick. In outline, each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ inches in diameter. Each head shall be provided with flanges not less than $\frac{3}{4}$ inch thick and extending outward $2\frac{1}{2}$ inches from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head must be smooth and must give a true and uniform bearing for the staves. To secure the desired true and uniform bearing the surfaces of the flanges of the head must be either ground or machined. The flanges shall be slotted on the outer edge, so as to provide for two $\frac{3}{4}$-inch bolts at each end of each stave, said slots to be $\frac{13}{16}$ inch wide and $2\frac{3}{4}$ inches, center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace $\frac{3}{8}$ inch thick, extending down the outward side of the head not less than 2 inches.

There shall be for each head a cast-iron headliner 1 inch in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ inches in diameter. This headliner shall be fastened to the head by seven $\frac{5}{8}$-inch cap screws, through the head from the outside. Whenever these headliners become worn down $\frac{1}{2}$ inch below their initial surface level at any point of their surface, they must be replaced with new ones. The metal of these headliners shall be hard machinery iron and should contain not less than 1 per cent of combined carbon.

The staves shall be made of 6-inch medium steel structural channels $27\frac{1}{4}$ inches long and weighing 15.5 pounds per lineal foot. The staves shall have two holes $\frac{13}{16}$ inch in diameter, drilled in each end, the center line of the holes being 1 inch from the end and $1\frac{3}{8}$ inches either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but must not exceed $\frac{5}{16}$ inch.

The interior or flat side of each stave shall be protected by a liner $\frac{3}{8}$ inch thick by $5\frac{1}{2}$ inches wide by $19\frac{3}{4}$ inches long. The liner shall consist of medium steel plate and shall be riveted to the channel by three $\frac{1}{2}$-inch rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 inches from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once reriveted, but no liner shall be replaced by a new one except as the whole set is changed.



PLAN FOR RATTLER.

Any test at the expiration of which a stave-liner is found detached from the stave or seriously out of position shall be rejected. When a new set of liners has been placed in position, before being used for testing, the rattler shall be charged with 400 pounds of shot of the same sizes, and in the same proportions as provided in Item 9 and shall then be run for 1,800 revolutions at the usual prescribed rate of speed. The shot shall then be removed and a standard shot charge inserted, after which the rattler may be charged with brick for a test.

No set of liners shall be used for more than one hundred tests. The record must show the date when each set of liners goes into service, and the number of tests made upon each set.

The staves when bolted to the heads shall form a barrel 20 inches long, inside measurement, between headliners. The liners of the staves must be so placed as to drop between the headliners. The staves shall be bolted tightly to the heads by four $\frac{3}{4}$-inch bolts, and each bolt shall be provided with a lock nut, and shall be inspected at not less frequent intervals than every fifth test and all nuts shall be kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

ITEM 8. *The frame and driving mechanism.*—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates and shall be fastened thereto by bolts at not less than four points.

It shall be driven by gearing whose ratio of driver to driven is not less than one to four. The counter shaft upon which the driving pinion is mounted shall not be less than $1\frac{15}{16}$ inches in diameter, with bearings not less than 6 inches in length. It shall be belt-driven, and the pulley shall not be less than 18 inches in diameter and $6\frac{1}{2}$ inches in face. A belt of 6-inch double-strength leather, properly adjusted, to avoid unnecessary slipping, should be used.

ITEM 9. *The abrasive charge.*—The abrasive charge shall consist of cast-iron spheres of two sizes. When new, the larger spheres shall be 3.75 inches in diameter and shall weigh approximately 7.5 pounds (3.40 kilos) each. Ten spheres of this size shall be used.

These shall be weighed separately after each ten tests, and if the weight of any large sphere falls to 7 pounds (3.175 kilos), it shall be discarded and a new one substituted, provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that so far as possible the large spheres shall compose a graduated series in various stages of wear.

When new, the smaller sized spheres shall be 1.875 inches in diameter and shall weigh approximately 0.95 pound (0.43 kilo) each. In general the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly as possible 300 pounds. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 inches in diameter, drilled in an iron plate $\frac{1}{4}$ inch in thickness, or weigh less than 0.75 pound (0.34 kilo). Further, the small spheres shall be tested by passing them over the above plate, or shall be weighed after every ten tests, and any which pass through or fall below the specified weight shall be replaced by new spheres, and provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small sphere shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon	Not less than 2.50 per cent.
Graphitic carbon	Not more than 0.25 per cent.
Silicon	Not more than 1.00 per cent.
Manganese	Not more than 0.50 per cent.
Phosphorus	Not more than 0.25 per cent.
Sulphur	Not more than 0.08 per cent.

For each new batch of spheres used, the chemical analysis must be furnished by the maker or be obtained by the user, before introducing into the charge, and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

THE OPERATION OF THE TEST.

ITEM 10. *The brick charge.*—The number of brick per test shall be ten for all bricks of so-called "block size," whose dimensions fall between from 8 to 9 inches in length and $3\frac{3}{4}$ inches to $4\frac{1}{4}$ inches in thickness.[1] No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

ITEM 11. *Speed and duration of revolution.*—The rattler shall be rotated at a uniform rate of not less than $29\frac{1}{2}$ nor more than $30\frac{1}{2}$ revolutions per minute, and 1,800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin of not to exceed ten revolutions will be allowed for stopping. Only one start and stop per test is generally acceptable. If from accidental causes, the rattler is stopped and started more than once during a test, and the loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

ITEM 12. *The scales.*—The scales must have a capacity of not less than 300 pounds, and must be sensitive to one-half of an ounce, and must be tested by a standard test weight at intervals of not less than every ten tests.

ITEM 13. *The results.*—The loss shall be calculated in percentage of the initial weight of the brick composing the charge. In weighing the rattled brick, any piece weighing less than one pound shall be rejected.

ITEM 14. *The records.*—A complete and continuous record shall be kept of the operation of all rattlers working under these specifications. This record shall contain the following data concerning each test made.

1. The name of the person, firm or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street, or contract which the sample represented.
4. The brands or marks upon the bricks, by which they were identified.
5. The number of bricks furnished.
6. The date on which they were received for test.
7. The date on which they were tested.
8. The drying treatment given before testing, if any.
9. The length, breadth and thickness of the bricks.
10. The collective weight of the 10 large spherical shot used in making the test at the time of their last standardization.
11. The number and collective weight of the small spherical shot used in making the test, at the time of their last standardization.
12. The total weight of the shot charge, after its last standardization.
13. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them right at the beginning of the test.
14. Certificate of the operator of the number of charges tested since the last standardization of shot charge.
15. Certificate of the operator of the number of charges tested since the stave liners were renewed.
16. Certificate of the operator that the requisite number of revolutions were made, under the prescribed conditions, upon the staves after the last relining, before a brick test was made.

[1] Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.

17. The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test as shown by the indicator.

18. Certificate of the operator as to number of stops and starts made in each test.

19. The initial collective weight of the ten bricks composing the charge and their collective weight after rattling.

20. The loss calculated in percents of the initial weight; and the calculation itself.

21. The number of broken bricks and remarks upon the portions which were included in the final weighing.

22. General remarks upon the test and any irregularities occurring in its execution.

23. The date upon which the test was made.

24. The location of the rattler and name of the owner.

25. The certificate of the operator that the test was made under the specifications of the American Society for Testing Materials and that the record is a true record.

26. The signature of the operator or person responsible for the test.

27. The serial number of the test.

In event of more than one copy of the record of any test being required, they may be furnished on separate sheets, and marked duplicates, but the original record shall always be preserved intact and complete.

ACCEPTANCE AND REJECTION OF MATERIAL.

ITEM 15. *Basis of acceptance or rejection.*—Paving bricks shall not be judged for acceptance or rejection by the results of individual tests, but by the average of no less than five tests. Where a lot of bricks fail to meet the required average, it shall be optional with the buyer whether the bricks shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in Item 16.

ITEM 16. *Range of fluctuation.*—Some fluctuation in the results of the rattler test, both on account of variation in the bricks and in the machine used in testing, are unavoidable and a reasonable allowance for such fluctuations should be made, wherever the standard may be fixed.

In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than 2 per cent, then the portion of the lot represented by that test shall at once be resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than 2 per cent the required standard, then that portion of the lot shall be rejected.

If in any lot of brick two or more tests exceed the permissible maximum, then the buyer may at his option reject the entire lot, even though the average of all the tests executed may be within the required limits.

ITEM 17. *Fixing of standards.*—The percentage of loss which may be taken as the standard will not be fixed in these regulations, and shall remain within the province of the contracting parties. For the information of the public, the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications.

	General average loss.	Maximum permissible loss.
	Per cent.	*Per cent.*
For bricks suitable for heavy traffic	22	24
For bricks suitable for medium traffic	24	26
For bricks suitable for light traffic	26	28

Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer, and should be governed by the kind and amount of traffic to be carried, and the quality of paving bricks available.

ITEM 18. *Culling and retesting.*—Where, under Items 15 and 16 a lot or portion of a lot of brick is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete, the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot of portion under test.

ITEM 19. *Payment of cost of testing.*—Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also Item 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it, shall be paid by the seller, whether the material is finally accepted or not.

SECTION II.—VISUAL INSPECTION.

It shall be the right of the buyer to inspect the bricks, subsequent to their delivery at the place of use, and prior to or during laying, to cull out and reject upon the following grounds:

ITEM 20. All bricks which are broken in two or chipped in such a manner that neither wearing surface remains intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where brick are rejected upon this ground, it shall be the duty of the purchaser to use them so far as practicable in obtaining the necessary half bricks for breaking courses and making closures, instead of breaking otherwise whole and sound brick for this purpose.

ITEM 21. All bricks which are cracked in such a degree as to produce defects such as defined in Item 20, either from shocks received in shipment and handling, or from defective conditions of manufacture, especially in drying, burning or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

ITEM 22. All bricks which are so off-size, or so misshapen, bent, twisted or kiln-marked, that they will not form a proper surface as defined by the paving specifications, or align with other bricks without making joints other than those permitted in the paving specifications.

ITEM 23. All bricks which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this Item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude, as provided in Item 2, and if in either or both tests, the bricks fall beyond the maximum rattler losses permitted under the specifications, then all bricks having the same objectionable appearance may be excluded, and the seller must pay for the cost of the test. But if under such procedure, the bricks which have been tested as objectionable shall pass the rattler test, both tests falling within the permitted maximum, then the buyer cannot exclude the class of material represented by this test and he shall pay for the cost of the test.

ITEM 24. All bricks which differ so markedly in color from the type or average of the shipment as to make the resultant pavement checkered or disagreeably mottled in appearance. This Item shall not be held to apply to the normal variations in color which may occur in the product of one plant among bricks which will meet the rattler test as referred to in Items 15, 16, and 17, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture.

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BULLETIN OF THE
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No. 24.

Contribution from the Forest Service, Henry S. Graves, Forester.
December 31, 1913.

COTTONWOOD IN THE MISSISSIPPI VALLEY.

By A. W. Williamson,
Forest Examiner.

IMPORTANCE OF COTTONWOOD.

Cottonwood is one of the important timber trees native to this country. Twenty years ago it had almost no value; to-day its wood is extensively used and the demand for it is much in excess of the supply. It is a tree of very rapid growth. On rich lands yields of from 4 to 5 cords of wood per acre per year are not uncommon. Yields of over 30,000 feet of merchantable timber can be obtained in 40 years, and 20 years is sufficient to produce timber of fair dimensions. Cottonwood is especially valuable in the Mississippi Valley region, where it offers exceptional inducements for the conservative handling of timberlands in which it occurs, or for forest planting.

Cottonwood's importance as a tree for artificial forestation is attested by the fact that it has claimed the attention of forest planters in many foreign countries, such as France, Germany, Belgium, and Argentina. (See Pl. VI, fig. 1.) By careful selection certain French horticulturists have developed from this species improved varieties which are said even to exceed the original form in rapidity of growth. In South America, at the mouth of the Parana River in Argentina, a very extensive and lucrative industry has been developed by growing cottonwood on land subject to frequent inundations. (See Pl. II.) These plantations furnish saw timber from 10 to 12 inches in diameter. On account of the scarcity of timber there, boards but 3 or 4 inches wide and 6 feet long find a ready market at high prices. Such plantations pay as high as 15 per cent on the money invested.

In this country the possibility of growing cottonwood commercially, either by planting or by favoring it in natural stands, has not yet received the attention it deserves. Though cottonwood plantations as a source of future supply of pulpwood justify consideration, the tree's chief value will lie in the production of fuel and farm timbers, and for windbreaks, for which it has been extensively planted by farmers in the Middle West. (See Pl. VI, fig. 2.)

A special study has been made of cottonwood by the Forest Service, to determine more definitely its characteristics and the general practicability of forest management. The investigations were confined largely to the Mississippi Valley region, where cottonwood is commercially important. The conclusions reached in this bulletin, therefore, apply chiefly to this region, and more particularly to the southern part of the valley. The conclusions in regard to planting, however, apply wherever cottonwood can be grown.

ANNUAL CUT AND PRESENT SUPPLY.

The lumber cut of cottonwood for 1911 approximated 198,630,000 board feet. In addition a considerable amount of cottonwood was used for other purposes. Slightly over 25,000 cords, or 14,000,000 board feet, were used in 1911 for pulpwood, much of which, however, probably came from the black cottonwood. The veneer industry consumed another 35,000,000 feet, and over half as much more is reported to have gone into slack cooperage, while nearly 62,000 cords were used for excelsior. The total cut, therefore, was somewhat over 300,000,000 feet, board measure, exclusive of firewood.

As compared with important timber trees the cut of cottonwood is small, yet considering its limited commercial range and its restricted local occurrence it must be regarded as a tree of considerable commercial importance. The demand for its lumber is, in fact, in excess of the supply, as reflected by the rise in its mill-run value from $10.37 in 1899 to $18.12 in 1911. The value of the total cut of cottonwood for 1909, the last year for which values of products were obtained by the Bureau of the Census, was over $6,000,000, of which the lumber cut represented $4,794,424. Table 1 shows the cottonwood lumber cut for 1911, together with the estimated average value f. o. b. at the mill, arranged by States.

TABLE 1.—*Amount and value of cottonwood lumber cut in 1911.*

State.	Number of active mills reporting.	Quantity.		Value.	
		Thousand board feet.	Per cent.	Total.	Average per thousand feet.
Total	1,950	198,629	100.0	$3,599,157	$18.12
Arkansas	80	52,457	26.4	967,307	18.44
Louisiana	41	48,037	24.2	900,694	18.75
Mississippi	51	32,687	16.5	659,624	20.18
Missouri	265	11,545	5.8	188,876	16.36
Tennessee	55	8,308	4.2	129,854	15.63
Iowa	130	5,452	2.7	106,532	19.54
Wisconsin	63	4,339	2.2	62,178	14.33
Michigan	147	3,713	1.9	54,952	14.80
Minnesota	72	3,082	1.6	42,008	13.63
Washington	8	3,056	1.5	53,025	17.35
Maine	64	2,620	1.3	37,833	14.44
Ohio	154	2,288	1.2	41,527	18.15
Texas	11	2,248	1.1	39,902	17.75
Alabama	16	2,015	1.0	25,691	12.75
All other States	793	16,782	8.4	289,154	17.23

Cottonwood is so widely and irregularly distributed that an estimate of the amount of standing timber would be almost impossible to obtain. Its commercial range is confined principally to the bottom lands of the Mississippi River and similar situations for some distance up many of its tributaries, especially the Missouri, Ohio, Arkansas, St. Francis, Yazoo, and Red Rivers. Probably the largest supply of valuable cottonwood timber is in the States of Arkansas, Louisiana, Mississippi, and Missouri. It is also common in the northern Mississippi Valley, especially Minnesota, Iowa, Illinois, and Indiana, but in this region it attains far less importance than in the South. A large proportion of the cut reported from these States probably comes from planted groves. In the remainder of its range it occurs too scatteringly to warrant extensive lumbering operations.

Although no estimate is available, there is every indication that the supply is failing. The output of cottonwood lumber fell off 52 per cent between the years 1899 and 1911. The State of Arkansas, which still leads in the production of cottonwood lumber, manufactured less than one-half as much in 1911 as in 1899. In all probability the maximum cut of this species has long since been passed.

CHARACTER OF THE WOOD.

The wood, although relatively not strong, is strong in proportion to its weight. It is tough, and extremely light when well dried, a cubic foot weighing about 24.25 pounds, or nearly the same as white pine. Its specific gravity is 0.3889 (Sargent). The fuel value is 51 per cent of that of white oak, and the amount of ash is 0.96 per cent of the dry weight of the wood (Sargent). The modulus of rupture, which is an index of breaking strength, is 84 per cent, while the modulus of elasticity, which is an index of stiffness, is 67 per cent of that of white oak.

The wood has a close, even texture, is quite porous, and only moderately hard. It displays numerous although obscure medullary rays. Because of its tendency to warp, it requires care in seasoning, unless properly piled. The heartwood is glossy light brown in color. The sapwood, which seldom is more than 2 or 3 inches thick, is creamy white. When seasoned the wood is almost tasteless and odorless. As a rule it is easily worked and finished, but occasionally trees seem to produce a tougher fiber which tears badly in sawing and planing, producing a "brashy" or "woolly" surface. Lumber of this character is often termed "white" cottonwood, in distinction from the yellow.

These two kinds of wood are thought by some lumbermen to come from distinct species. Woodsmen often claim that they can tell

the difference in the tree—pointing out that the "white cottonwood" has a closer, thinner bark of darker color than the thick, rough, grayish bark of the "yellow cottonwood." There seems to be no doubt, however, that both the white and the yellow varieties come from the same species.

The yellow cottonwood is not only darker in color, but is said to work more easily and be less subject to warping. It is probably the wood of the older trees. The white cottonwood appears to come usually from comparatively young trees of rapid growth, which, however, may be as large as older, slower-growing individuals. Yet white cottonwood lumber is by no means typical of the younger stands, which usually saw out wood of excellent quality.

USES.

Cottonwood has a wide range of uses, and for certain purposes is being used in place of much more costly woods, such as white pine and yellow poplar. It was for a time marketed as "sap poplar," but was soon accepted by the wood-using industries under its true name.

In the manufacture of shipping cases for food products cottonwood is used in large quantities. When properly seasoned it imparts little if any taste or odor to the contained product. For this reason also it is in demand for candy pails and the like. Its toughness and lightness give cottonwood additional fitness for boxes and crates. Experiments by the Forest Service [1] to determine the comparative strength of packing boxes of various woods demonstrated beyond question that, when taken weight for weight, the cottonwood box outclasses in strength similar containers of practically all other species extensively used—such as white pine, yellow pine, spruce, hemlock, and red gum. Bulk for bulk, cottonwood is surpassed only by red gum.

A large amount of cottonwood is manufactured into rotary veneer, which is employed for a wide variety of purposes, cores or filling of built-up lumber, panels, bottoms, sides and backs of drawers, lightweight veneer boxes, cases, egg crates, baskets, and trunks. Such veneer opens up a large field of uses for cottonwood from which it would otherwise be excluded because of its liability to warp. Three-ply veneer three-eighths of an inch thick is much stronger than solid wood five-eighths of an inch thick. Considerable cottonwood veneer, 3 to 5 ply, is exported to Europe for backing upon which to lay more costly woods in the manufacture of musical instruments, cases, and furniture.

Since cottonwood in close stands early clears itself of branches, select logs cut out a fairly high percentage of clear and upper grades

[1] Forest Service Circular 47, "Tests of Packing Boxes of Various Woods."

of lumber. Cottonwood is used but is not popular for flooring, partition, siding, and ceiling. When properly stained it makes a remarkably attractive wainscoting, door panel, balustrade, etc. When exposed to weather as siding it warps and decays unless painted. Cottonwood is extensively used for barn framing and roof boards, and is employed to some extent in freight cars and as bridge planking. Because of its clean, white, uniform surface, it is excellent for pyrography. It is used extensively by the manufacturers of slack cooperage for staves and heading.

Cottonwood has for some time been used in the manufacture of pulp. It is reduced usually by either the soda or the mechanical process, but also yields well to the sulphite method. Experiments by the Forest Service show that cottonwood makes a pulp almost identical in character with that from aspen, which is used more than any other wood for the production of soda pulp. At the present time cottonwood is used extensively on the Pacific coast for the production of "news" paper. Cottonwood ground pulp has a comparatively short fiber and must usually be mixed with about 60 per cent of long-fibered pulp, such as that of spruce, in order to make finished paper. The pulp produced by the soda and sulphite processes is used to some extent in the manufacture of book and magazine paper.

Cottonwood has also been used considerably for excelsior, for which it is highly prized. Although statistics are not available to show the quantity of fuel cut from this timber, it is undoubtedly large.

PRESERVATIVE TREATMENT.

One serious objection to cottonwood is its rapid decay when exposed to the weather or when in contact with the soil. To make the wood more durable, preservative treatment will in many cases be necessary. Because of its open, porous texture, cottonwood takes preservatives readily, the treatment requiring comparatively small expense.

Treated cottonwood fence posts have given excellent service. It is probable, therefore, that cottonwood can be grown to post size and the posts creosoted at less expense than much more durable species of slower growth which require no treatment. Creosoting tanks of the type described in Farmers' Bulletin 387, "The Preservative Treatment of Farm Timbers," can be easily constructed and will prove thoroughly effective in treating stakes, posts, or small poles for farm use.

Although tests are being made with treated cottonwood railroad ties, it seems doubtful if they will prove sufficiently strong for use under heavy traffic.

If properly treated, cottonwood should prove valuable for mine props, especially where only short or moderate lengths are required. The large proportion of the wood now wasted in tops and removed in thinnings could be used for this purpose.

Siding or rough lumber exposed to the weather can be made resistant to decay by the application of paint containing a large proportion of oil. The smooth, hard surface of the cottonwood board takes paint readily without absorbing a large quantity.

STUMPAGE VALUES AND LOGGING COSTS.

SAW TIMBER.

The greater and wider use of cottonwood has naturally resulted in a gradual and steady upward course of its stumpage value. Twenty-five years ago well-formed cottonwood trees standing almost at the edge of the river and often containing more than 2,000 or 3,000 board feet of high-grade lumber could be purchased for 50 cents a tree. Even more recently cottonwood could be obtained almost anywhere along the Mississippi River for 50 cents a thousand feet board measure on the stump, and logs were often delivered at the mill for $4 per thousand feet. In the early days the idea was generally prevalent that the cottonwood in the Mississippi Valley bottom lands was almost inexhaustible. Even to-day many stumpage owners are not aware of cottonwood's true value, and often sell merchantable cottonwood timber, accessibly situated, at extremely low prices.

It appears to be a general view among representative millmen in the lower Mississippi Valley that a stumpage price of $5 per thousand is none too high for average cottonwood timber accessibly situated near the river bank and requiring no longer hauls than from a quarter of a mile to a mile. Stumpage prices as high as $8 are reported as actually being paid for standing timber of the best quality when especially accessible.

The money value of timber on the stump, as of any other commodity, should be determined by the actual cost of producing it, plus a fair profit to the producer. In artificial plantations the true stumpage value can be readily determined. In virgin timber, which is a free gift of nature, the cost of production can not be determined, and the actual stumpage prices are controlled chiefly by demand and supply. Theoretically the stumpage value of virgin timber is the difference between the actual market value of the lumber and the cost of producing it. The latter figure should include not only the costs of logging and manufacturing, but also the operator's profit. In other words, if a lumber company must be assured of a profit of p per cent on all money invested in stumpage, logging, and manufacturing,

the stumpage value, S, could be expressed by the following formula, in which M represents the market value of the manufactured lumber at the mill, L the logging costs, and Mf the sawmill costs:

$$S = \frac{M}{1.0p} - (L + Mf)$$

From the data supplied by the principal cottonwood concerns the following lumbering costs per thousand board feet may be considered typical for the lower Mississippi region: Felling, 65 cents; hauling, $1 (for maximum of three-fourths mile); rafting, 85 cents (50 to 75 miles), or barging, $1 for average of 100 miles; which makes a total of approximately $5.50. Where the logging operation is within 25 to 30 miles of the mill and the timber comparatively close to the river, the total cost for logging and transportation may easily fall as low as $4. The cost of sawing is believed by many millmen to be at least $5 per thousand. Often, however, $4.50 will probably cover the mill end of the operation, including the interest on the investment, cost of upkeep, and all overhead charges. Under average conditions, therefore, the cost of manufactured lumber, f. o. b. at the mill, exclusive of stumpage and manufacturer's profit, should not exceed $10 per thousand board feet, and may be considerably less.

The market value for manufactured cottonwood lumber mill-run in Missouri, Arkansas, Tennessee, Louisiana, and Mississippi was, in 1909, $19.09 per thousand feet, f. o. b at the mill, varying in different States and at different seasons between $18 and $22. Boxboards practically clear of knots and from 13 to 17 inches wide sold during the same year for from $40 to $50, while wider boards of the same quality, termed panel stock, ran proportionally higher. The lowest grades quoted in the Forest Service Record of Wholesale Prices of Lumber, viz, No. 2 common, ranged from $12 to $15. These quotations, since they include no item for freight charges or selling costs, are, of course, considerably lower than the wholesale prices at the larger lumber markets, such as New York or Chicago.

Assuming $19 per thousand board feet as a typical f. o. b. mill value for the manufactured lumber, and logging and milling as $5.50 and $5, respectively, the formula works out as follows, where a profit of 20 per cent to the manufacturer is allowed:

$$S = \frac{M}{1.0p} - (L + Mf) = \frac{\$19.00}{1.20} - (\$5.50 + \$5.00) = \$5.33.$$

If several years are required to complete the logging operation, however, this formula should also include the interest on the money invested in stumpage, and the stumpage value in such an event would be found by deducting the interest at a fair borrowing rate, say 6 per

cent, for the average length of time invested. The equation then reduces to the form $S=\frac{\$5.33}{1.06^n}$, where n equals the number of years required for the operation. For a 2-year operation in the case considered $S=\frac{5.33}{1.06}=\$5.03$.

It is believed that this will represent a fair average for cottonwood in the southern part of the valley. In the river bottoms of the Northern States, such as Minnesota and Wisconsin, cottonwood yields wood of poor quality, and has a comparatively low value. Practically no grade corresponding to the wagon-box boards cut from the southern cottonwood is obtained. The best grades are usually put together and sold locally for heavy shipping cases, the manufacture of cheap furniture, or for the framework, roofing, and siding of farm buildings. Such lumber is sawed principally by portable mills and brings about $22 per thousand delivered to the consumer. The poorer grades, aggregating possibly one-third of the cut, are usually worth little more than $12 to $14 per thousand for the manufacture of packing boxes or crates, or for use about the farm. An average of $19 per thousand for mill-run delivered would probably be a representative price in this region. From this must be deducted the cost of transporting the lumber either by wagon, railroad, or both, to the point of delivery. A man and team at $4.50 per day should haul on good roads 1,000 feet per trip and load the lumber on the cars. Assuming a possible distance capacity for the team of 18 miles per day, the cost of hauling should not exceed $1.50, $2.25, and $3, respectively, for hauls of 3, 4½, and 6 miles, assuming an average day of 10 hours. Freight charges to be deducted will seldom be over 60 cents per thousand for the short shipments usually necessitated. Deducting $2.75 for hauling (4½ miles) and freight, the lumber at the mill should be worth $16.25. Where the mill is set up on the tract to be logged the total cost of delivering logs at the mill should not exceed $2 or $3 per thousand, which would allow one-quarter to one-half mile haul. Portable sawmills will usually saw cottonwood for from $4.50 to $5.50 per thousand. Since in this case the stumpage value itself represents the profit of the owner, the stumpage-value formula would here take the form $S=M-(L+Mf)$. By substituting in the formula what are considered to be representative values for this region, we get $S=16.25-(2.50+5.00)=\$8.75$. With no lumber haul, as when the mill is located on a railroad, the value per thousand would be the full $19 and lumber near the mill might easily be worth $10 or more on the stump. This higher stumpage value for cottonwood in the northern part of the valley, in spite of its poorer quality, is due partly to the lower logging cost from having the mill at the

source of supply, and partly to the better demand for what in the South would be classed as rather low grades.

The stumpage value of planted groves of cottonwood in the prairie regions, especially in southern Minnesota, Iowa, the Dakotas, Kansas, and Nebraska will necessarily be higher than in the natural stands outside this region. The general adaptability of cottonwood for barn framing, roofing, stable flooring, bridge planking, etc., gives it a ready sale at prices ranging from $20 to $22 per thousand mill-run. The cost of sawing, however, is also greater in this region, due to the limited amount of logs available at a given set-up and the few mills operating. It should, however, seldom exceed $7.50 per thousand. The cost of cutting and yarding the logs will, on the other hand, in some degree offset this increase, and should not exceed $1.50 per thousand. Since generally most of the lumber will be used by the owner himself or his neighbors, it should have a value at the mill of at least $21, with a correspondingly high stumpage value. In this case the formula works out:

$$S = 21 - (1.50 + 7.50) = \$12.$$

In this region, therefore, we find the highest stumpage value prevailing anywhere, and in this figure no account is taken of the protective value of the groves for windbreak purposes.

CORDWOOD.

Considerable quantities of cottonwood are sold in the form of cordwood—principally as pulpwood stock and as stave and excelsior bolts. In determining the stumpage value of such material, the market value of the final product, whether pulpwood, stave, or excelsior, is not considered, for it would entail a very technical study of the costs of manufacture. Instead, the price generally offered for the cordwood delivered is taken as the value per thousand in the stumpage equation, from which is deducted the costs, L, of producing the delivered cordwood. The stave and excelsior companies usually pay about $6 per cord delivered. At present paper companies do not, as a rule, obtain cottonwood from the Mississippi region, but till recently purchased such material at prices that brought the total cost delivered at mills in Ohio and Indiana up to approximately $7 per cord. The woods operations are alike for these various products, except that excelsior stock and sometimes pulpwood stock must be peeled in the woods while green. The cost of felling and peeling and cutting into lengths is about $1.25 per cord. A haul of a fourth to a half mile to the river seldom exceeds $1 per cord. Barging is a variable cost, dependent upon the distance, but under average conditions should not exceed $2 per cord for 75 miles, including loading and unloading. If a profit of 20 per cent be allowed to the

operator or contractor, the stumpage value per cord for stave or excelsior bolts would be worked out as follows:

$$S=\frac{6}{1.20}-4.25=\$0.75$$

The costs of transportation either by barge or railroad or both to the paper mills in the North Central States is so great that it is doubtful if a much larger stumpage price than the above would be paid for peeled pulpwood in the Mississippi Valley between Cairo and Memphis. Such stock does not seem ever to have been bought farther south. As a matter of fact, when such stumpage has been bought, it has seldom been considered worth more than 50 cents. On the other hand, if pulpwood should be grown on suitable land within 10 or 20 miles of the mill, and provided the delivered cordwood was worth $7.50 per cord to the company, the stumpage would be far more valuable. Under such conditions the cost of cutting, hauling, and shipping might easily be reduced to $4, giving the following results:

$$S=\frac{7.50}{1.20}-4.00=\$2.25$$

As a rule, however, a company in need of pulpwood stock would not require that the stumpage return a profit, and unless the operations took at least half a year probably no interest at all would be charged to the purchase of stumpage. If the company had grown its own trees the determination of the stumpage cost would include all necessary interest charges of this character, but the stumpage value would be merely the difference between the value of the wood delivered at the mill and the cost of cutting and transportation, together with any profit that might be demanded on such costs. The question as to whether or not the growing of the trees has resulted in profit or loss can not affect the actual stumpage value. If the latter is insufficient to cover the costs of growing the wood, the loss must be charged against the planting investment, not against the stumpage. Therefore, the formula should properly be—

$$S=M-(1.0pL)=\$7.50-(1.20\times 4.00)=\$2.70.$$

RANGE.

The common cottonwood, *Populus deltoides* Marsh, occurs principally along the margins of streams from the Province of Quebec and the shores of Lake Champlain down the Connecticut River and along the Atlantic coast south to northern Florida; and westward, except in the higher altitudes of the Appalachians, through the Mississippi Valley to the foothills of the Rocky Mountains in New Mexico; and northward into southern Alberta. East of the Appalachians it is very scattering and rare. It follows up the tributaries

of the Mississippi River into the Great Plains region, where it is found at altitudes as high as 9,000 feet, but is confined to the river banks.

BOTANICAL CHARACTERISTICS.

Populus deltoides Marsh is usually known merely as cottonwood, but in certain sections is variously spoken of as Carolina poplar, yellow cottonwood, white cottonwood, big cottonwood, cotton tree, broadleaved cottonwood, Vermont poplar, necklace poplar, and still other local names. It has been introduced into Europe, where it is variously termed the Swiss white poplar, the black Italian poplar, the Canadian poplar, etc.

The leaves, which are usually from 3 to 6 inches long and equally board, are more or less triangular in shape, sharply pointed, prominently veined, and edged with glandular incurved teeth. The leaves on the more vigorous shoots in the top of the tree are frequently more than twice the length of the others. When crushed they emit a pleasant balsamic odor. The leafstalks are flattened on the sides for most of their length, but become more round near their junction with the twig. Cottonwood has long, pointed, greenish or reddish-green winter buds, which are very resinous and are somewhat flattened. The bark on the younger stems and branches is comparatively thin and of a light grayish-yellow color, tinged with green, but on the trunks of older trees becomes rough, thick, and deeply furrowed and is dark grayish in color.

In cottonwood the male and female flowers are borne on different trees (dicœcious). Seed therefore is borne only on female individuals, whereas the male trees are always barren. The flowers bloom from February to April, according to the latitude, and always before the leaves are out. They occur in long pendulous catkins. The female catkins mature toward the last of April or May, even before the leaves have attained full growth, at which time the 3 or 4 valved capsules open and shed large quantities of "cottony" seed that is carried far and wide by the wind. To this abundant production of downy-coated seed cottonwood owes its name as well as the disfavor in which it is sometimes held for lawn and street planting. It is a very simple matter, however, to overcome this objection by propagating only male trees. (See fig. 1.)

Populus deltoides is easily distinguished from the swamp cottonwood (*Populus heterophylla* Linn.), which has somewhat the same range, by its distinctly triangular-shaped leaves and its thicker, more closely attached bark. In the western extension of its range cottonwood grows with norrow-leaved cottonwood (*P. angustifolia* James), which is readily disinguished by its narrow lanceolate leaves.

SILVICAL CHARACTERISTICS.

DEMANDS UPON SOIL AND MOISTURE.

Cottonwood requires abundant soil moisture. It is not adapted to dry situations, such as ordinary upland sites with thin soil. It

FIG. 1.—Catkins, twigs, and leaf and flower buds of cottonwood. *a*, Pistillate catkin; *b*, enlarged scale of staminate catkin; *c*, staminate catkins; *d*, twig with leaf-buds; *e*, twig with flower-buds; *f*, twig, showing angularity; *g*, longitudinal section of leaf-bud; *h*, longitudinal section of flower-bud.

seldom establishes itself naturally where surface moisture is lacking, although, if planted on such sites, it frequently makes very satis-

factory growth, provided the roots can readily penetrate to a moist subsoil. Moisture is especially essential for the germination of cottonwood seed. It is this characteristic which accounts for the occurrence of the species on sandbars and overflow lands along streams and the borders of swamps and lakes.

Cottonwood, however, is in no sense a swamp tree, in spite of a rather general impression to the contrary. True, it withstands extremely long periods of inundation by the spring floods of the Mississippi River and its tributaries. Yet such overflows are not comparable to standing swamp water, which is deficient in the free oxygen essential to root function. In the spring floods to which the cottonwood is subject there is a continual current of water about the base of the trees. After the recession of the floods the water table descends often many feet below the ground surface. The upper soil strata are then thoroughly drained either toward the river or toward the back sloughs. Cottonwood will not show thrifty development on very poorly drained situations.

The quality of the soil itself affects the local occurrence of cottonwood but little. With abundant moisture the tree appears to thrive on poor, sandy sites as well as on the stiffer clay soils. On typical overflow lands, however, the rich, alluvial deposits of comparatively close, fine texture seem to conserve the moisture better than the coarse, deep sands. The best growth of cottonwood therefore occurs as a general rule on the former sites. Yet if the water table is near the surface during the growing season, very well-developed stands are found on rather infertile sandy or gravelly soils.

LIGHT REQUIREMENTS.

Cottonwood is extremely exacting in its light requirements. Without doubt it is the most intolerant species in the Mississippi bottomlands. Young cottonwoods are seldom found coming up under a normally dense stand of older trees. Even under exceptionally favorable soil and moisture conditions the young growth seldom survives for longer than one summer. Direct overhead light alone is scarcely enough to encourage reproduction. This extreme intolerance of shade remains with the tree throughout its life and accounts for the rapid thinning out of pure cottonwood stands with age. The intolerance of cottonwood is also responsible for the ease with which the trees clear themselves of side branches in close stands.

Compared with the tolerant pine or spruce, cottonwood of the same age has fewer trees to the acre. Thus at 35 years, when the trees average 20 inches diameter breasthigh, an acre will bear only 50 to 75 trees. The amount of wood produced per acre, however, is as great, if not greater, in white pine or spruce stands.

As with all species, the demand of cottonwood upon light varies with the amount of moisture in the soil, and occasionally trees survive under shade, provided moisture conditions are exceptionally favorable.

SUSCEPTIBILITY TO INJURY.

WIND.

Cottonwood is fairly windfirm, but in exposed situations it is likely to suffer from breakage on account of the brittleness of its branches. Windfall is common only on rather wet, poorly drained sites, where the roots lie near the surface. In well-drained soils cottonwood sends a rather stocky taproot, well reenforced with spreading laterals, down to a depth of 4 to 6 feet.

FUNGI.

Damage from fungi is not serious in the Mississippi River Valley. On unfavorable sites, however, especially in plantations outside its natural habitat, injuries from this source are often more or less pronounced. Of the several diseases, the most common and injurious is the "rust," caused by a fungus (*Uredo melampson medusæ* Thüm.), which is said materially to check the growth of the tree. This and many other leaf fungi are likely to do considerable injury to young trees in the nursery. In such instances it is advisable to burn the diseased leaves at the end of the growing season. Spraying with Bordeaux mixture is often effective.

Of the fungi attacking the wood of cottonwood, *Fomes applanatus* (Pers.) Gill [1] (*Elvingia megaloma* (Lév.) Murrill), is one of the most noticeable, but seldom gains entrance to perfectly sound trees. It attacks both heartwood and sapwood, causing a white rot that weakens and sometimes kills the tree. Wounded and fire-scarred trees are most liable to such injury. Other fungi attack the twigs and branches of cottonwood. These include species of *Cytospora* and *Nectria*, which cause dead spots or cankers in the bark, resulting in the death of branches beyond the point affected. Very little is known of some of these fungi, but as a rule they seldom do serious damage in cottonwood stands, and expensive measures for combating them are rarely justified. The ordinary procedure in case of widespread fungous attacks is to cut out all diseased trees and burn or remove them.

The cottonwood in the southern United States is subject to damage by the mistletoe, *Phoradendron flavescens* (Pursh.) Nutt.[2] Injuries

[1] Heald. F. D. A disease of cottonwood due to *Elvingia megaloma*, Nebr. Agr. Expt. Sta. Rept., vol. 19, pp. 92–100, 1906.

[2] Bray, W. L. The mistletoe pest in the Southwest. Bureau of Plant Industry Bulletin 166, February, 1910.

from this source are especially pronounced in the Red River Valley region of Texas and Oklahoma. Although the apparent injury is confined to the branches, the vitality of the whole tree is weakened through loss of nourishment withdrawn by the parasite.

INSECTS.

Many species of insects attack cottonwood, but with few exceptions cause no serious damage to the trees. The exceptions are found in one or two species, the larvæ of which bore into the living bark and sapwood, sometimes doing serious damage. If any serious injury by insects is found, the matter should be reported to the Bureau of Entomology, Department of Agriculture, Washington, D. C. Specimens of the insects or of their work should accompany such a report.

ANIMALS.

The thin bark of young cottonwoods is relished by field mice and rabbits, and at times large numbers of trees are completely girdled by their gnawing. Girdling by mice is most likely to occur under snow or in deep grass. Rodents may destroy most of the young trees or cuttings in a cottonwood plantation, which makes planting on grassy sites a hazardous undertaking. Seedlings, however, usually sprout from the root collar below the injury. In the case of natural reproduction, where the trees come up so densely that the loss of 75 per cent or more during the first two or three years is of little consequence, the damage from this source is but slight.

Cattle are very fond of the green shoots and foliage of cottonwood and should be kept out of young growth, either natural or planted, for the first three or four years, after which they will do but little harm.

FIRE.

Cottonwood is very susceptible to fire injury while young, but by the time it is 15 to 20 years old has produced a fairly fire-resistant bark. Fires are, moreover, not likely to start or become serious on bottoms subject to overflow. Young cottonwood stands should be carefully protected against fire.

REPRODUCTION.

FROM SEED.

Cottonwood reproduces readily both by seed and by sprouts. Female trees bear seed in abundance practically every year. They begin to seed very early in life, probably when not over 10 years of

age, and continue to bear vigorously throughout most of their existence. The trees of the two sexes are usually unevenly distributed, and female trees may sometimes be greatly outnumbered by males. The seed matures, as a rule, during May or early June, when the capsules open.

The seeds are very minute, usually about an eighth of an inch long, and sometimes no more than one-twelfth of an inch wide. They are oblong, obovate, rounded at the apex, rather light brown in color, and are surrounded at the large end with a fringe of long, white, silky hairs which gives them a characteristic cottony appearance and renders them extremely light and buoyant. Seed dissemination, therefore, takes place easily, the seed often being carried by the wind miles from the parent tree. Seed dispersion is also effected by the overflow waters, which frequently leave fertile seed on the muddy alluvial deposits far from the parent tree.

The germinating power of freshly collected mature cottonwood seed is comparatively high, varying from 60 to 90 per cent. With proper moisture conditions the seed germinates very quickly. The vitality of the seeds, however, is very short-lived, few, if any, germinating when more than a month old. Seeds three weeks old have a germination of 50 per cent.

Cottonwood is fastidious with regard to a suitable germinating bed. Reproduction is almost entirely restricted to situations where the mineral soil is exposed, and even on such sites the seed demands abundant moisture. This explains why cottonwood seldom starts on any situations except moist, newly formed sandbars or abandoned cultivated fields.

Reproduction by seed in the Mississippi bottom lands is probably dependent to a considerable degree on the overflows which saturate the surface soil. Even on areas not inundated the water table may rise so near the surface as to supply the seed with sufficient moisture. Reproduction seems to be surest on situations which have been inundated, and every exceptionally high overflow is followed by a rank growth of young cottonwoods wherever the shade and ground cover will permit. It is probable that another benefit of this high water lies in the thin silt deposit left by the receding water, which affords an ideal germinating bed.

FROM SPROUTS.

Cottonwood reproduces also from sprouts, both from the stump and from the roots. Root sprouts, however, are comparatively infrequent and from the standpoint of management are of minor consequence. Stump sprouts originate both at the base of the stump and the root collar, and at the top of the stump from the cambium between the bark and the wood.

COTTONWOOD NEARLY 7 FEET IN DIAMETER, SHOWING THICK, DEEPLY FURROWED BARK, TYPICAL OF THE SPECIES.

EXTENSIVE COTTONWOOD PLANTATION NEAR BUENOS AIRES, SOUTH AMERICA.

There is an important relation between the height of the stump and the proportion of sprouts arising respectively from the root collar and the top of the stump.[1] Of the two kinds of sprouts, only the former is of practical importance from the standpoint of renewing a stand commercially. Sprouts from the top of the stump are dependent upon the stump for support, as they are unable at once to form an independent root system of their own. Cottonwood stumps, however, decay rapidly, and as the mechanical support of the new sprouts thus becomes weakened they are easily sloughed off and eventually are almost always thrown by the wind. The number of vigorous sprouts from the root collar decreases with the height of the stump; other conditions being favorable, very low stumps (below 6 inches) invariably produce vigorous sprouts. Very little dependence can be placed upon stumps more than 15 inches high to sprout vigorously from the root collar. In fact, stumps higher than 11 inches produce a disproportionately large number of sprouts from the top of the stump. If dependence is to be placed upon sprouts from the root collar, it would therefore seem advisable to cut the stumps as low as 6 inches, if possible, and certainly not higher than 12 to 14 inches. Table 2 shows the relation between the height of stump and the kind and vigor of sprouts.

TABLE 2.—*Relation between height of stump and kind and vigor of sprouts.*

Height of stump.	Number of stumps.	Average number of sprouts on root collar.	Average number of sprouts on top of stump.	Average number of vigorous sprouts on stump.	Average height of sprouts.	Height of stump.	Number of stumps.	Average number of sprouts on root collar.	Average number of sprouts on top of stump.	Average number of vigorous sprouts on stump.	Average height of sprouts.
Inches.					*Feet.*	*Inches.*					*Feet.*
4	11	14	0	14	10.00	23	9	0	42	31	5.58
5	16	11	0	11	6.66	24	26	0	26	12	6.25
6	21	12	2	14	7.25	25	16	0	45	20	5.00
7	18	9	5	12	9.16	26	11	0	38	16	4.50
8	12	7	14	20	9.33	27	14	0	38	18	4.75
9	27	13	20	25	8.75	28	21	1	56	18	4.50
10	31	5	8	13	7.41	29	8	0	46	18	4.66
11	20	8	2	10	8.25	30	36	0	60	20	4.00
12	16	9	30	39	6.66	31	29	0	51	22	4.16
13	32	5	48	53	7.00	32	31	0	44	15	5.08
14	51	7	21	28	7.16	33	20	0	54	21	4.50
15	42	6	17	23	7.66	34	27	0	63	14	3.66
16	23	3	32	35	6.16	35	18	0	37	8	4.25
17	57	2	36	32	7.08	36	25	0	67	10	3.16
18	37	0	42	35	7.16	37	13	0	74	9	3.66
19	7	0	62	20	6.00	38	9	0	35	10	4.58
20	41	1	44	30	5.50	39	5	0	57	12	3.41
21	23	0	24	18	6.16	40	2	0	65	10	3.16
22	10	0	37	22	5.25	41	3	0	61	16	4.58

[1] "The Cottonwood (*Populus deltoides*): A Tree Study," Master's Thesis, by Julius V. Hofmann, University of Minnesota, April, 1912.

The sprouting capacity of stumps also depends upon their age. After 30 years of age it becomes weak and at 45 years almost ceases. Age, however, does not seem to affect the method of sprouting. Apparently the most vigorous sprouting capacity, as determined by the number of sprouts per stump, is somewhere between 15 and 25 years of age. It should be realized, however, that the smaller number of sprouts from stumps below this age is not an indication of lack of vigor, since a small stump can not for physical reasons support as many sprouts as a large one.

The capacity to sprout, like reproduction from seed, is also governed to a great extent by the light supply. Vigorous sprouts do not develop under the shade of the forest. In stands where only the best trees are cut, coppicing, because of the shade of surrounding trees, is almost sure to fail.

Another factor of basic importance in affecting coppice reproduction is the season of cutting. Sprouts readily form after felling in winter or early spring, whereas stumps cut in summer or early fall seldom give rise to thrifty sprout growth.

The conclusions just given apply particularly to the northern part of the Mississippi Valley in the vicinity of Red Wing, Minn. In the lower Mississippi Valley, where cottonwood is of larger commercial importance, very little evidence of this form of reproduction was found. Comparatively few young, vigorous trees are cut. Lumbering usually removes only the larger mature trees, whose sprouting capacity is limited and whose stumps are partially shaded by trees left standing on the ground. Lumbering, furthermore, is usually carried on most extensively in the summer and fall, when the sprouting capacity of the trees is lowest. Probably this combination of circumstances is responsible for the almost entire absence from the lower Mississippi bottom lands of cottonwoods of sprout origin. The adaptability of this system of coppice reproduction to the Mississippi region can be determined, therefore, only after actual experimentation. There is, however, little reason to doubt that young stands of cottonwood in that region can be readily renewed by coppice, provided logging is carried on during the season of most vigorous sprouting and extended also to young trees.

CHARACTER OF STANDS.

Cottonwood occurs both in pure stands and in mixture with other species. Either of these conditions is unstable, the pure stand evolving gradually into a mixed one from which the cottonwood may eventually be eliminated. This is due to cottonwood's demand for full sunlight. As the old trees die they are succeeded by stands of more tolerant species which have come up under partial shade. In fact, the very continuance of cottonwood in natural stands seems

almost dependent upon accidents which result in openings in the stand and thus provide the light needed for the growth of young cottonwoods. The main agencies of this character in the Mississippi Valley are the river itself, which is continually building up new lands, and destructive winds, which often clear wide swaths through the forest.

PURE STANDS.

Cottonwood when young normally grows in pure stands. Since cottonwood reproduction is so dependent on full overhead light, such stands are restricted to sites that at the time of seeding were unshaded. Pure cottonwood is therefore most common on the following situations: (*a*) Newly formed islands and bars built up by deposition; (*b*) old lake and river bottoms which have been filled in by sediment; (*c*) old fields which have been abandoned and have reverted to natural growth; and (*d*) open areas within the forest caused by hurricanes or fires. Probably 90 per cent of the pure cottonwood stands are on exposed areas outside of the river levees. The value of cleared farm land in the Mississippi Valley is so great that practically none has been abandoned in recent years, unless subject to overflow. In many cases mature stands of cottonwood have been cut from such areas in order to use them for farming.

Pure stands are seldom extensive, although in the southern half of the region they are found in more or less solid bodies over hundreds of acres adjoining the river. Pure stands are always even-aged, or at least consist of even-aged groups. Where several age classes are present their arrangement is usually governed by the order of succession in the formation of new land by the river. The youngest stands lie nearest the river on the ground last built up, and as one progresses from the river toward the levees one passes through successive belts of even-aged cottonwood, each very similar to the preceding, except that the age and consequent size become greater and greater. The regularity of this succession, however, is usually broken by stands of black willow.

Pure stands of cottonwood are extremely dense. They undergo very rapid thinning with age, however, as might be expected from fast-growing intolerant trees when starting in dense thickets. It is not unusual to find two-year-old thickets of this character with probably 40,000 living trees to the acre. The seeds, in fact, frequently germinate as close as 2 or 3 inches apart, but thousands of the young plants die from lack of light or moisture very soon after germinating. At the age of 10 years there are seldom more than 700 to 800 trees left, and at 25 years this number is reduced to about 120 trees per acre. (See Pl. III.)

MIXED HARDWOOD STANDS.

Cottonwood grows in mixture either with willow or with other hardwoods. It is more often found with the hardwoods on the better drained glades and ridges throughout the bottom-land areas. The mixture differs in the north and south portions of the valley. The predominating species associating with cottonwood in the upper Mississippi Valley are silver maple, white elm, river birch, sycamore, boxelder, and ash. Other species are butternut, shellbark hickory, black walnut, pin oak, hackberry, and coffeetree. Most of these occur also through much of the lower valley region, especially sycamore, ash, hackberry, and boxelder. Several other species, however, which are abundant in the South, become scarce or entirely disappear from the composition as one proceeds north through the upper valley. This is true particularly of red gum, tupelo, cypress, pecan, willow oak, overcup oak, and cow oak. In addition to those already listed, the following trees of minor value are often found with cottonwood in either or both parts of the valley: Honey locust, black locust, dogwood, mulberry, pawpaw, red elm, redbud, and hawthorn. Perhaps the most characteristic associates of cottonwood in the northern part of the valley are the silver maple and white elm, while sycamore, hackberry, and red gum occur most abundantly with it in the south. Nearly all of the associated species are present in the central sections of the valley, including extensive bottomland areas in Missouri, Arkansas, Illinois, Tennessee, and Kentucky.

In certain parts of the bottoms, three classes of situations supporting forest growth may be recognized, namely, the "glades," the "ridges," and the "back sloughs." The sloughs remain under water during the larger part of the growing season and their characteristic forest growth is cypress and tupelo gum. Cottonwood practically never grows there. The bottoms subject to overflow for from a few weeks to several months are sometimes spoken of collectively as the "glades." These in turn may be irregularly divided by low "ridges," which are seldom over 6 feet in elevation, and often slope almost imperceptibly to the level of the glades. The ridges and the glades, however, are often not clearly defined, and even where they are well marked the forest composition seems to be but little governed by them. Sycamore, pecan, shellbark hickory, and boxelder are possibly more common on the better drained ridges.

In mixed hardwood stands the cottonwood occurs in all proportions from only one to two trees per acre up to nearly a pure stand. Frequently cottonwood occurs in small groups on the lower depressions. Such groups may have 10, 20, or more trees. At times the cottonwood, either single trees or groups, seems to be restricted to higher elevations, apparently because at the time of seeding the

lower land was under water. This indirect influence of topography accounts for much of the variation in the character of occurrence of cottonwood in this mixed stand.

If the cottonwood is well represented in such a mixed stand, there is often almost the appearance of a well-defined two-storied forest, in which the more shade-enduring species, such as elm, sycamore, ash, hackberry, or oak, are partially overtopped by the much faster growing cottonwood. By the fortieth or fiftieth year, however, the stand has usually opened enough to give the associate species room for growth. During the next 50 years these gradually fill in the space left vacant by the death of the cottonwoods. At the age of 100 years such stands may contain less than half a dozen large cottonwoods to the acre.

A pure stand of cottonwoods develops in a similar manner into a mixed stand as the trees reach maturity. In fact, during the early life of the pure cottonwood stands there is often an understory of small sycamore, ash, elm, maple, and other species, which upon examination will generally show the same age as the cottonwoods. These associates, gradually augmented by others that come in as cottonwoods die, ultimately occupy the ground to the exclusion of the latter.

COTTONWOOD-WILLOW STANDS.

In the Mississippi Valley cottonwood is frequently associated with various willows, which compete with it in occupying newly made lands and bars. Black willow (*Salix nigra* Marsh.) is the principal associate in the lower valley, while in the north the almondleaf or peachleaf willow (*Salix amygdaloides* Anderss.) appears to be more common. The latter, together with the small longleaf or sandbar willow (*Salix fluviatilis* Nutt.), which is common throughout the whole region, seems to appropriate nearly all the available open areas along the upper river, affording very little chance for the reproduction of cottonwood, which apparently seeds somewhat later. Cottonwood-willow stands, therefore, are infrequent in the north and usually contain a very small proportion of cottonwood. They are, however, comparatively common in the lower valley. Here the black willow and cottonwood seem to grow on more even terms, and both species make almost equally rapid growth for the first 20 to 25 years. The cottonwood, however, continues to develop, and on many situations may ultimately crowd the willow out of the stand. Since, however, the latter seems to be better adapted to poorly drained land, it is not uncommon to find it crowding out the cottonwood on wet, mucky soils. The cottonwood-willow stands are therefore of a very temporary character, few being over 30 years

old. For this reason they are of comparatively little importance from the standpoint of management.

FORM AND GROWTH OF INDIVIDUAL TREES.

Cottonwood is one of the tallest trees east of the Rocky Mountains. Under favorable conditions it attains a height of more than 175 feet, and mature trees within its optimum range are seldom less than 125 feet high. The maximum height recorded by the Forest Service is 190 feet. Diameters of from 4 to 6 feet are not unusual (Pl. I), and trees on well-drained bottomlands in the Mississippi Valley have measured nearly 10 feet through at the stump.

In forest stands of average density, cottonwood prunes itself of branches remarkably well, producing a long, straight bole, clear of limbs for a distance of from 60 to 80 feet, with comparatively little taper. The crown remains narrow and pointed until the trees reach 25 to 40 years of age, after which it becomes more branchy and spreading. In the open or when planted in single rows, cottonwood produces a short, stocky stem, which is likely to divide within 20 or 30 feet of the ground into several large, irregular branches, forming a long, open, wide-spreading crown.

Cottonwood develops a stout taproot from 3 to 6 feet long, reenforced by numerous wide-spreading laterals. Wherever successive layers of alluvial soil are deposited by the river about the base of the tree, new side roots appear to develop along the buried part of the trunk.

The bark of mature trees is extremely thick and rough, and firmly attached. At 10 years the bark at the base of the tree averages about half an inch in thickness; at 35 years, about an inch; and on old trees sometimes more than 2 or 3 inches. The bark is characterized by rough, narrow ridges, separated by wide, irregular connecting furrows. (Pl. I.)

Notwithstanding its large dimensions, cottonwood seldom reaches great age. It is unusual to find sound trees of this species over 125 years old. The maximum age recorded by the Forest Service is 166 years, and it is probable that 200 years is about the maximum longevity of the species.

It is a tree of remarkably fast growth, especially during early life. After about 40 years of age, however, the growth rate in height declines rapidly, although the trees continue to increase in girth at a moderate rate. On alluvial bottomland soils which are fairly well drained an average annual height growth of from 4 to 5 feet and a diameter growth of two-thirds of an inch are not at all unusual for the first 25 years. Trees have been measured that were 83 feet tall at 12 years and 100 feet at 15 years. Table 3 shows the average

height and diameter of bottomland trees at different ages. Even on fresh, well-drained upland situations, where cottonwood seldom occurs naturally, planted trees will easily increase 2 to 3 feet in height annually for the first 20 years.

GROWTH AND YIELD OF STANDS.

The most important question in considering the growth of a species is, How much wood will it yield per acre? The growth of cottonwood stands was determined by means of 100 sample plots laid off in pure stands of cottonwood on overflow lands in the lower Mississippi Valley.

The growth of stands depends on the growth of the individual trees and on the number of trees per acre. Pure stands of cottonwood are open in character. Table 3 shows the average number of trees per acre at different ages. It is apparent from this table that the rapid growth of individual cottonwoods is to some extent offset by the comparatively small number of trees to the acre. At 35 years 59 trees remain, of which 53 are 14 inches and over in diameter. By 40 years the total has diminished to 48, nearly all of which are at least 14 inches in diameter. The rapid decrease in number is apparent when it is seen that at 10 years there were 699 trees, at 20 years 163, and at 30 years only 80. (See Pl. IV.)

Because of the open character of cottonwood stands very heavy yields of lumber per acre are rare. By utilizing all trees down to 14 inches on the stump to a top diameter of 12 inches, it is doubtful if even the best pure stands will cut over 40,000 board feet per acre. Yet, considering the early age at which cottonwood reaches merchantable size, the yield compares favorably with that of such trees as white pine and Douglas fir, which, though larger, take a much longer time to reach such size. Measurements of a large number of plots in the Mississippi River region show that fully stocked pure stands yield an average of 31,000 feet board measure in 40 years, and that some stands at this age will cut as high as 36,000 feet to the acre.

Table 3 gives the average yields from fully stocked stands of cottonwood at different ages in board feet and cubic feet. The average annual yield of a stand is obtained by dividing the total yield per acre by the age. From Table 3 it is apparent that the number of board feet produced per year is greatest when the stand is about 35 years old, after which the average annual production gradually falls off. Theoretically, therefore, the best time to cut cottonwood is when its average annual production begins to decline. As shown later, however, other factors may affect the time of cutting.

TABLE 3.—*Growth and yield of cottonwood (Populus deltoides Marsh) in pure, fully stocked stands in the Mississippi Valley.*

Age.	Number of trees per acre.		Average size.		Yield per acre.			Average annual yield per acre.		
	14 inches and over.	All trees.	Diameter breast-high.	Height.	Stem wood.	Scribner decimal.	Doyle.	Stem wood.	Scribner decimal.	Doyle.
Years.			*Inches.*	*Feet.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*
5	--	-----	2.0	22	650	-----	-----	130	---	---
6	--	-----	2.8	29	875	-----	-----	146	---	---
7	--	1,450	3.5	36	1,025	-----	-----	146	---	---
8	--	1,163	4.2	43	1,250	-----	-----	156	---	---
9	--	900	5.0	49	1,500	-----	-----	167	---	---
10	--	699	5.7	56	1,800	-----	-----	180	---	---
11	--	558	6.4	61	2,175	-----	-----	198	---	---
12	3	452	7.1	67	2,600	-----	200	217	---	17
13	8	375	7.8	72	3,050	800	700	235	62	54
14	15	320	8.5	76	3,500	1,600	1,300	250	114	93
15	22	276	9.2	81	3,850	2,400	1,900	257	160	127
16	29	243	9.8	85	4,150	3,200	2,600	259	200	163
17	34	217	10.5	88	4,400	4,000	3,300	259	235	194
18	37	195	11.1	92	4,575	4,900	4,100	254	272	228
19	40	178	11.7	95	4,750	5,800	4,900	250	305	258
20	43	163	12.3	97	4,900	6,600	5,700	245	330	285
21	45	150	12.8	100	5,025	7,600	6,500	239	362	310
22	47	140	13.4	102	5,125	8,600	7,500	233	391	341
23	49	130	13.9	104	5,250	9,600	8,400	228	417	365
24	50	121	14.5	106	5,350	10,700	9,500	223	446	396
25	52	114	15.0	108	5,450	11,900	10,700	218	476	428
26	53	106	15.5	109	5,525	13,200	12,000	213	508	462
27	54	99	16.0	111	5,600	14,700	13,400	207	544	496
28	55	92	16.5	112	5,675	16,300	15,100	203	582	540
29	55	86	16.9	114	5,750	18,100	17,100	198	624	590
30	55	80	17.4	115	5,825	20,300	19,200	194	677	640
31	55	75	17.9	116	5,875	22,700	21,400	190	732	690
32	55	70	18.3	117	5,950	24,900	23,500	186	778	734
33	55	66	18.8	119	6,025	26,800	25,300	183	812	767
34	54	62	19.3	120	6,075	28,300	26,600	179	832	782
35	53	59	19.7	121	6,150	29,400	27,500	176	840	786
36	52	57	20.2	123	6,200	30,100	28,200	172	836	783
37	51	53	20.6	124	6,275	30,400	28,700	170	822	776
38	50	51	21.1	125	6,325	30,700	29,100	166	808	766
39	49	50	21.5	126	6,375	30,900	29,300	163	792	751
40	48	49	22.0	127	6,425	31,000	29,300	161	775	733
41	46	48	22.4	128	6,475	31,000	29,400	158	756	717
42	45	45	22.9	129	6,525	31,100	29,500	155	740	702
43	44	44	23.4	130	6,575	31,000	29,500	153	721	686
44	43	43	23.8	131	6,625	31,000	29,500	151	705	670
45	42	42	24.2	132	6,675	30,900	29,500	148	687	656
46	40	40	24.7	133	6,725	30,800	29,500	146	670	641
47	38	38	25.1	134	6,775	30,700	29,500	144	653	628
48	37	37	25.6	135	6,825	30,600	29,500	142	638	615
49	34	34	26.0	136	6,875	30,500	29,500	140	622	602
50	32	32	26.5	136	6,900	30,300	29,400	138	606	588

Similarly, the current annual production in cubic feet or cords per acre culminates at the age of 12 years, at which time approximately 500 cubic feet per acre annually is being produced. The average annual growth, however, continues to increase up to 16 years, when it attains 255 cubic feet per year, against only 221 cubic feet at 12 years. It is plain, therefore, that if the object of growing cottonwood is to produce the maximum amount of solid wood per acre per year, a rotation of approximately 16 years will give the desired results. The reason why the average annual growth in board feet per acre culminates later than the average annual production in cubic feet is because the board-foot production does not begin until the

trees are about 12 years old and because the number of board feet to each cubic foot increases as the tree increases in size. In logs of large diameters each cubic foot will saw out more than 7 or 8 board feet, whereas in small logs there may be only 2 or 3 board feet.

Table 4 gives the yield of pulpwood for stands from 5 to 20 years old under the most favorable conditions of growth. Older stands are not considered, because the maximum average annual yield in cords per acre occurs at a considerably earlier age than 20 years.

TABLE 4.—*Yield of pulpwood per acre in the lower Mississippi Valley.*

Age.	Total yield.		Average annual yield.	Age.	Total yield.		Average annual yield.
Years.	*Cubic feet.*	*Cords.*	*Cords.*	*Years.*	*Cubic feet.*	*Cords.*	*Cords.*
5	630	6.6	1.3	13	4,460	47.0	3.6
6	810	8.3	1.4	14	4,690	49.4	3.5
7	1,020	10.7	1.5	15	4,830	50.8	3.4
8	1,320	13.9	1.7	16	4,910	51.7	3.2
9	1,700	18.0	2.0	17	4,960	52.2	3.1
10	2,330	24.5	2.5	18	4,990	52.5	2.9
11	3,100	32.6	3.0	19	5,010	52.7	2.8
12	4,050	42.6	3.5	20	5,020	52.8	2.4

The volumes of the trees were determined up to a top diameter of 4 inches inside the bark, except where the stem was too crooked or branchy. The cubic-foot volume was converted into cords by dividing it by 95, a liberal factor for converting solid cubic feet into stacked measure. The cordwood figures are for peeled wood. Where unpeeled wood is purchased with the intention of running it through a barking machine at the mill these figures will be too low. The bark constitutes about 22 per cent of the total volume. The figures in the table therefore represent only 78 per cent of the total cubic contents. The largest average annual yield is obtained at 13 years, at which time there is a total stand of 47 cords. The growth and yield tables are naturally restricted in their application to cottonwood stands in the central and southern United States, where the measurements were made, and particularly to overflow lands along the rivers and streams. Observations on the growth of cottonwood in Iowa and Minnesota would seem to indicate, as might naturally be expected, that the yield in the northern part of the country would fall considerably below that in the South.

It was difficult to find pure cottonwood stands in Iowa and Minnesota in which normally stocked plots could be laid off. Only a half dozen plots were measured, ranging from 25 to 55 years. The results are given in Table 5.

TABLE 5.—*Yield of cottonwood stands on upland soil in Iowa and Minnesota.*

Location.	Age.	Number of trees per acre.	Average diameter breast-high.	Average height.	Yield per acre, Scribner.		Remarks.
					To 12-inch top.	To 10-inch top.	
	Years.		*Inches.*	*Feet.*	*Bd. ft.*	*Bd. ft.*	
Lee County, Iowa	25	108	13.0	80	1,700	5,100	Scattered, with many associate species.
Do	25	88	13.8	82	4,100	6,600	Do.
Allamakee County, Iowa.	45	131	15.3	84	12,900	15,600	Pure stand.
Jackson County, Iowa.	50	80	18.3	100	15,800	18,100	Very dense pure stand.
Monona County, Iowa.	55	88	16.5	94	13,100	16,800	In Missouri Valley, less humid climate, dense, pure.
Scott County, Minn.	56	25	24.8	107	15,000	18,100	Maple, elm, ash, etc., in mixture.

It is probable that some of these stands have been cut to a slight extent, but it is not likely that on upland soil in this region cottonwood will cut more than 20,000 feet per acre at 50 years of age. At this age, however, it has already reached maturity and is losing rather than gaining. Yields of between 15,000 and 20,000 board feet ought to be possible in 35 to 40 years. One or two plantations in Iowa on good bottomland soil have yielded more, as may be seen from Table 6.

TABLE 6.—*Yield of cottonwood on bottomland soil in Iowa.*

Location.	Age.	Number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre.	Original spacing.
	Years.		*Inches.*	*Feet.*	*Bd. ft.*	*Feet.*
Harrison County	34	126	14.5	87	23,850	7½ by 6
Monroe County	35	137	13.3	77	24,500	8½ by 8½

At least one of the plantations has occasionally been thinned. Moreover, the trees had plenty of room for early growth, and it is probable that they were cultivated for the first few years. In the case of these plantations, however, the estimates take in all straight logs to a top diameter of 6 inches, for even such small-sized material is actually sawed up for farm use. Considering, however, only logs 10 inches and over in diameter, northern stands of cottonwood will probably seldom yield more than two-thirds as much saw timber as stands of the same age in the lower half of the valley.

MANAGEMENT.

ADAPTABILITY OF COTTONWOOD.

If cottonwood stands are to be maintained permanently some system of management is essential. Its demand for plenty of direct

light must in particular be fully met. In logging mixed stands the trees which are of little value to the lumbermen, and are therefore commonly left standing after the removal of the cottonwood and many other merchantable species such as ash, red gum, or oak, should also be taken out. The shade cast by these weed trees and by underbrush tends to prevent the reseeding of the area to the light-demanding cottonwood. Rarely does one find good restocking of this species except on wide clean openings, such as are sometimes made by hurricanes or by laying out logging roads, drainage ditches, and the like.

Even in pure cottonwood stands it is unusual to find satisfactory restocking after logging, under present methods. Pure stands after 40 or 50 years' growth thin out and expose the forest floor to sunlight, thereby inducing the entrance of undergrowth, such as poison ivy, pepper vine ("cow itch"), briers, dogwood, and privet, and occasional seedlings of the more tolerant species. After logging operations such growth is left in control of the area, and usually prevents the reproduction of cottonwood. Moreover, pure stands on the more recently made land along the river are sometimes culled over for the largest timber before all the trees are merchantable. This serves further to open up the stand. It is customary to cull pure stands on islands and bars along the river several times, at intervals of 5 to 10 years. Under such conditions there is little chance of securing cottonwood reproduction after the final cut, unless all undergrowth is removed and cottonwood is planted.

The opportunity for managing cottonwood conservatively in the Mississippi bottoms is in some respects unparalleled. Nowhere else in the United States are there large areas of overflow bottomland unfit for agriculture which can be bought for from $3 to $5 an acre. Taxes on the land form scarcely any burden. In parts of the valley all unimproved land outside the levees is assessed at a uniform value of $1 per acre. In the South the assessed value rarely exceeds $2 or $3, with a tax rate of about 20 mills. Fire hazard is usually negligible, due to the annual spring floods, which carry away a large proportion of the inflammable material. It is true that much of this material is again deposited along the river banks, but, as a rule, on such situations growing cottonwood on a commercial scale is out of the question. Whatever débris remains in the cottonwood stands after a flood, being water soaked, decays rapidly. Furthermore, even when fire is a menace, cottonwood at the age of 15 or 20 years has formed comparatively fire-resistant bark from one-third to two-thirds of an inch thick.

Neither insects nor fungi seem to be a serious menace to cottonwood in the Mississippi Valley. This comparative freedom from disease is probably due largely to the favorable conditions for forest growth characteristic of rich, alluvial lands. Trees which are making vigor-

ous growth on soils naturally adapted to their requirements are not predisposed to disease. Such trees if accidentally injured by wind, fire, or other agency, more readily heal over the wound. Cottonwood, in particular, grows so rapidly that even large wounds do not long remain exposed to infection by fungi.

Another important condition favoring management of the bottomlands is the ease of getting the timber out. The land best suited to the practice of forestry lies for the most part within 2 or 3 miles of the river, which is generally used for transportation. This renders logging inexpensive and obviates the necessity of constructing railroads. It also makes it feasible to leave seed trees which can be easily taken out after they have restocked the ground and at a cost per thousand feet but slightly in excess of that for the first operation.

Furthermore, cottonwood is commercially very valuable and is one of the fastest-growing trees in the United States. It yields lumber of good quality within 30 to 35 years. Seed production, moreover, is abundant and frequent. Under such favorable circumstances owners of cottonwood stumpage should give more attention to securing new crops of timber after lumbering on lands unfit for farming.

AREAS AVAILABLE FOR GROWING COTTONWOOD.

Though large areas of the Mississippi bottomlands, especially in southeastern Missouri and northeastern Arkansas, are being made tillable through extensive drainage projects, and still other areas will be reclaimed for farming by the extension of the present levee system, there are extensive tracts of rich alluvial land subject to annual overflow of from one or two weeks to several months which afford ideal conditions for the growth of cottonwood. Probably the largest part of this unprotected land is in the lower valley, yet from Cairo, Ill., to the head of the river there are in the aggregate large areas better adapted to forest growth than to agriculture. The total area of such unprotected land south of Cairo, Ill., is approximately 1,500,000 acres, distributed as follows: From Cairo to the mouth of the White River, 690,000 acres; from the mouth of the White River to Warrenton, Miss., 500,400 acres; and from Warrenton to the Head of the Passes, 277,000 acres. While a portion of this unprotected land is sufficiently elevated to warrant cultivation, not more than 10 or 15 per cent is at present in crops. Back of the levees there is considerable land poorly adapted to agriculture, such as sandy ridges or the beds of old sloughs which may still be inundated in very wet periods. While farm crops may be grown on the ridges for a few years, the soil soon becomes unproductive. In addition, there are bottomlands bordering many tributaries of the Mississippi, such as the Red, Arkansas, Yazoo, and St. Francis Rivers, which because of poor drainage or annual inundation are unsuited for farming.

Tree growing on lands outside the levees is to some extent hazardous on account of the erratic movements of the river. Through the tremendous erosive power of the Mississippi its banks are continually caving in and its course changing. Of the 1,500,000 acres of unprotected land now available for timber production there may be, at the end of 35 years, the period required to produce a merchantable stand of cottonwood, nearly a million acres unaffected by the river's action. Attempts at systematic management of cottonwood in this region should therefore be confined to areas where the river will not encroach upon the timber before it has matured. A fairly close approximation can usually be made of the distance which the river will cut back into the present bank within a given period of years by comparing the distance cut during the same number of years in the past.

PURE STANDS.

Cottonwood will not tolerate shade. Direct overhead light is essential at all stages of its growth. Cottonwood should therefore be logged clear. The common practice of cutting to a diameter limit, which removes only the largest trees, is entirely unsuitable. Cutting the largest trees enables the stumpage owner to make the first cut earlier, i. e., while many of the trees are still unmerchantable, and to cut the remainder within from 5 to 6 years, when they have had the benefit of the increased light. Sometimes an area is cut over three times in 10 years. After each cutting vines and low shrubs spring up in abundance and almost entirely preclude natural reproduction. These conditions justify the removal in one cut of all the cottonwood on the ground that can be profitably handled, regardless of its possibilities of growth if left for another 5 or 10 years. Twenty or 30 small trees, 15 to 18 inches in diameter breasthigh, yielding perhaps 3,500 or 4,000 board feet, might in another 10 years cut 10,000 board feet. These 10 years, however, represent nearly a third of the time required to grow a stand which will yield 29,000 feet per acre. If it is remembered also that by gradual cutting the initial cost necessary to clear away the excessive undergrowth is much increased the greater profitableness of the clear cutting system is evident.

NATURAL REPRODUCTION VERSUS PLANTING.

Under the clear cutting system the renewal of the stand may be obtained either by natural reproduction, secured by leaving seed trees on the cut-over area, or by planting. Natural and artificial restocking both have definite advantages. Other things being equal, planting is likely to be more costly, since it entails the raising or purchase of planting stock and the labor of setting it out. The cost of natural reproduction is represented by the value of the

seed trees if they are never utilized, or by the extra cost of removing them if they are taken out later. Planting, then, requires a cash outlay. Natural reproduction requires merely a curtailing of present profits. The greater present returns when no seed trees are left may often go a long way toward defraying the expense of planting.

It is questionable if planting would be wise where there is a reasonable certainty of securing new stands from natural seeding. Wherever conditions are favorable to seed germination, as on lands subject to overflow in the spring, but which is only moist when the seed falls, and is free from shrubs, vines, or herbaceous plants, natural reproduction is reasonably certain and less costly than planting. On low ridges or where spring overflow is uncertain, complete dependence can not be placed upon natural reproduction.

Planting insures a uniformly stocked stand; the spacing of the trees can be so regulated as to obtain more rapid growth during early life, thus shortening the rotation, and there is less chance of complete failure due to weeds or undergrowth, the absence of high water, or an unusually late flood which washes away the seed. On land where reproduction by either method is difficult planting is preferable. Planting, therefore, will in the future probably be preferred to natural reproduction in the Mississippi Valley.

REPRODUCTION BY SPROUTS.

Natural reproduction may be obtained either from sprouts or from seed. For several reasons sprout or coppice reproduction will probably be of comparatively minor importance in the lower valley. First, few stands of cottonwood less than 35 years old will be cut, by which time the sprouting vigor of the stumps has weakened. It is questionable whether sprouts from stumps of this age, even though originating at the root collar, will produce as large and vigorous trees as the parent stock. The sprouting vigor declines steadily after the tree is 20 to 30 years old. At this age the number of trees per acre is small. Consequently the sprouts would not form a sufficiently dense stand to clear themselves readily of side branches. These difficulties may be overcome, as, for example, by supplementing coppice growth by planting or natural seeding. From present indications it would seem that sprout reproduction is applicable only to stands managed for pulpwood on a rotation of 10 or 12 years. Pulpwood companies in the North which are planting this species will undoubtedly find the sprouting of cottonwood of great value in securing second growth. The coppice system of reproduction entails but small initial expense, and because of rapid growth makes possible short rotations. The young age of trees taken for pulpwood and the low stumps which it is possible to cut will insure vigorous sprouting from the root collar. Six inches should be the maximum

stump height. The trees should be cut during the winter or early spring and the ground be completely cleared in order to allow the coppice full sunlight. The only actual outlay necessary in securing a stand by this method will be that in connection with cutting back in July and August all but the most vigorous, well-formed sprouts on each stump. A system of this kind carried on in certain South American plantations of Carolina poplar (see p. 1), a male form of the cottonwood, is said to result in actually shortening the rotation from 10 to 7 years, or 30 per cent.

Where timber production is the object of management, reseeding or replanting the area will be the common method.

SEED TREES.

In a clear-cutting system abundant seed production and uniform seed distribution are of first importance. The next essential is a ground in condition suitable for germination of the seed and growth of the seedlings. Cut-over areas may often be seeded by adjoining timber. This is likely to be the case where the cutting areas are comparatively small, and where there are enough cottonwoods to restock the ground. Since pure stands of cottonwood are seldom more than a few hundred acres in extent and are usually long and narrow, paralleling the course of the river, reproduction from the adjoining stands should be successful wherever there are plenty of seed trees on the windward side of the tract to be seeded.

For natural restocking the seed of cottonwood can not be depended upon to scatter farther than 600 feet from the mother tree. Unless the cut-over area is less than 600 feet in width seed trees should be left on the area itself.

Seed trees represent an investment equivalent to the extra cost of logging them later after they have restocked the ground. If of poor quality for lumber, however, and very expensive to handle in a return cutting, they may be sacrificed, in which case the investment is represented by the actual stumpage value of the timber they would cut.

Seed trees should be left uniformly scattered over the area. They should be located with reference to the direction of the winds at the time of seeding. To facilitate the subsequent removal of the seed trees they may be located roughly in rows at right angles to the direction of the wind. This arrangement will permit the removal of the timber with the minimum amount of damage to the young growth, since all the logs from a given row may be hauled over the same logging road.

One mature seed-bearing tree reserved on each acre of cut-over land should be ample to restock the ground, and would allow for

windfall and breakage. If in the end two seed trees remained to even 3 acres, reproduction should be excellent. Since seed is borne in abundance each year, the trees will rarely be needed for longer than a year or two. One seed tree per acre would be equivalent to leaving parallel rows about 600 feet apart, with the trees approximately 50 feet apart in the rows.

In reserving seed trees the following considerations should be taken into account:

(*a*) Only female trees should be selected for seed production. Unfortunately, there seem to be no characteristics other than the flowers by which male and female trees may be readily distinguished. Seed trees should therefore be marked during the flowering or seed-bearing season. The flowers of the seed-producing trees are not conspicuous. They occur in the form of slender catkins, 6 to 10 inches long, on which the budlike flowers appear very small and scattered. During the seeding time the abundance of light "cotton" shed by these female catkins readily distinguishes the seed-bearing trees. The flowers of the male trees are, on the other hand, more showy—bright red or yellow in color—and the catkin fuller, wider, and denser, but not as long as the female catkin.

(*b*) In addition to one seed tree per acre, a number of male trees should also be left in order to insure proper fertilization of the female flowers. Fertilization is believed to be effected usually by insects, which carry the pollen from the staminate to the pistillate flowers. About every fourth tree should be a staminate one.

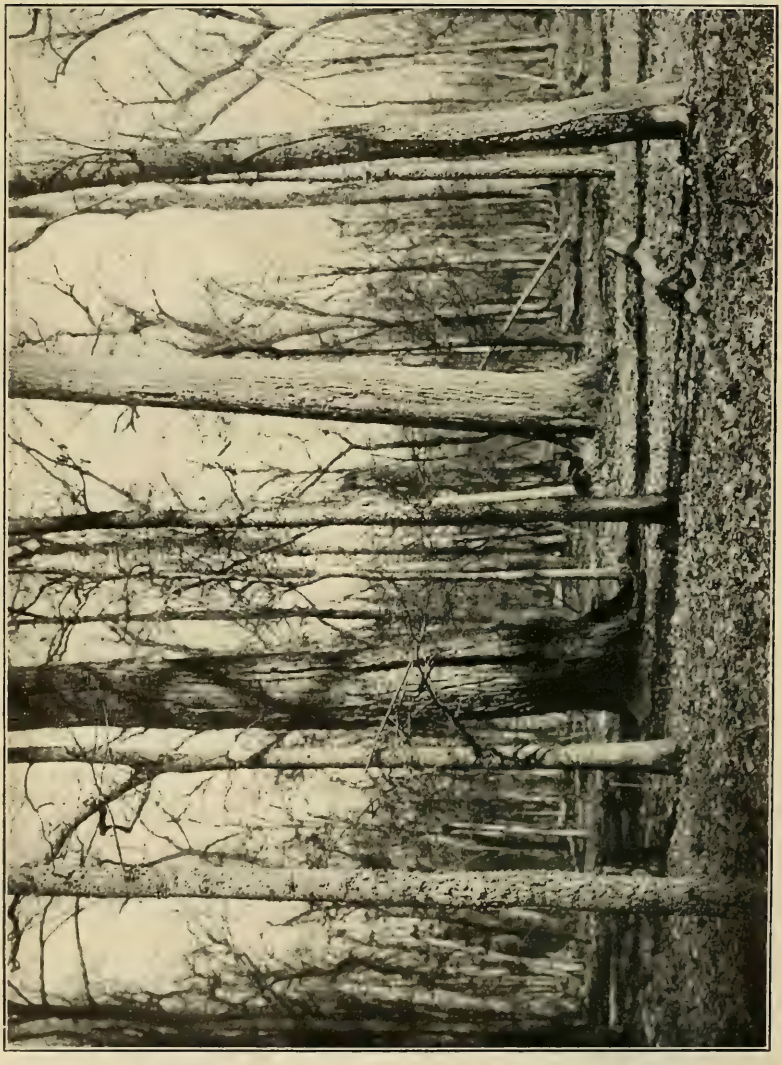
(*c*) Seed trees as far as possible should be the least merchantable individuals, since in this way the investment represented by the stumpage value of the trees left after logging is the least, whether they are later removed or not. Seed trees, however, should be thrifty and vigorous. Crooked, forked, or branchy trees, which would cut out a comparatively small amount of high-grade lumber, are usually just as vigorous and as suitable for seed production as the tall, clear, straight individuals. In fact, the larger the crown, the more seed is produced.

(*d*) Only windfirm trees should be left. On low, wet sites, where the soil is loose and soft, no seed trees should be reserved.

(*e*) Seed trees should be removed as soon as possible after young growth has become established, otherwise the shade will check the growth of many of the younger trees. There is less injury to the young growth if the seed trees are cut and removed before it attains much size. Since cottonwood often grows at the start at the rate of from 5 to 7 feet a year, it is advisable to cut the seed trees the year the young growth is established. If for any reason they can not be profitably removed and are likely to deteriorate before the next lumbering operation, it may sometimes be advisable to deaden them

FIG. 1.—MERCHANTABLE STAND OF PURE COTTONWOOD, 44 YEARS OLD, SHOWING CHARACTERISTIC STRAIGHT, CLEAR GROWTH.

FIG. 2.—PURE COTTONWOOD THICKET, 10 YEARS OLD, SHOWING EARLY DENSITY.



OVERMATURE SCATTERED COTTONWOODS WITH SMALLER UNMERCHANTABLE ASSOCIATES.

so that their shade may not suppress any of the young growth. Most pure stands, however, are accessible to the river, which makes it practicable, as a rule, to return for any seed trees within a year or two of the first cut. With only a few logs to handle it will often be possible to wait till high water and then float them out to the river bank, thus obviating the much greater expense of hauling. In such cases there would probably be no extra expense connected with leaving seed trees. If hauling were necessary, however, it might cost fully 50 per cent more to get out this scattered material. After the short interval of only a year or two, little if any additional swamping would be necessary to open up the former logging roads, but the haulers would lose considerable time in locating and loading the scattered logs and would probably get out no more than two-thirds as much per day as when working in heavier stands. If hauling under ordinary conditions costs $3 to $4 per thousand, it might increase in the latter instance to from $4.50 to $6 per thousand. The additional $1.50 to $2 per thousand feet would then represent the cost of leaving seed trees. If these are left as recommended, they should not average over 750 board feet per acre, which would make their cost at most run from $1.20 to $1.50 per acre.

PREPARATION OF THE GROUND.

Pure thickets of cottonwood, up to 20 or 25 years at least, are quite free from undergrowth, but at the age of 30 or 35 years a large variety of shrubs, vines, and weeds usually come up under the main stand. Such growth consists largely of peppervine, poison ivy, briers, privet, dogwood, and innumerable species of herbaceous character. In the more open mature stands undergrowth and weeds often cover most of the ground. In addition, there are often numerous suppressed or overtopped trees of less valuable species, such as sycamore, hackberry, and elm. Such trees are usually small, but if left after lumbering would soon develop spreading crowns and shade much of the area. All such growth is detrimental to cottonwood reproduction. To insure natural renewal of the stands, therefore, it will not be sufficient merely to leave seed trees, but in addition the ground must be cleared of all undergrowth. If the resulting slash is very abundant, it may be best to pile it with the cottonwood tops. In normally dense stands, however, this will seldom be necessary, since here the brush is not rank. Burning the slash will seldom be of benefit, except in the case of a rank growth of cane or weeds, which may be killed off by a carefully controlled surface fire. Surface fires do not run rapidly in most parts of the bottoms because of the small amount of inflammable material. Dry cottonwood leaves, moreover, are said to be much less inflammable than those

of most other hardwoods. In burning cane, briers, grass, and weeds special care is nevertheless advisable to keep the fire under control, and where adjoining stands of young timber might be injured it may even be important to surround the burning area with plowed furrows for fire lines.

No preparation of the ground is adequate which fails to leave the mineral soil exposed. Burning of slash under some circumstances may be sufficient, but as a rule it will be necessary to drag the surface with a spike-toothed harrow or similar implement. The cost of dragging should seldom exceed 50 cents per acre. Swamping of small trees and undergrowth can usually be effectually done for $1.50 to $2 per acre, making a total of $2 to $2.50 per acre for the preparation of the ground. In many bottom lands, however, half of this amount will be enough.

Grazing of hogs in the bottoms may serve to expose the mineral soil even better than dragging. Cattle, sheep, and goats may likewise assist in reducing the herbaceous growth. If logging is carried on during the summer, the underbrush and weeds will often get quite a start before the seed ripens the following spring, unless grazing is encouraged. As soon as reproduction starts, however, grazing should cease.

From the standpoint of preparing the ground there is plainly an advantage in logging during the late summer and fall, say from August to November, inclusive. Very little growth of weeds, grass, cane, etc., will come up on cleared areas after the first of August, and, moreover, the sprouting capacity of bushes and trees is low during these late months. Conditions in the bottoms will seldom permit of logging in the spring early enough to prepare the ground for the cottonwood seed of the same season. Wherever feasible, winter operations are entirely consistent with good management.

Proper preparation of the ground, however, will, in many instances, be out of the question. Where the undergrowth is especially dense and consists of vines, such as poison ivy or peppervine, the cost of eradicating it will frequently be prohibitive. Such areas can only be planted.

MIXED HARDWOOD STANDS.

Where cottonwood is the only species of great commercial importance on an area the aim should be to favor it alone. If, however, valuable species are growing with it, some of these may be favored as well. By favoring other species along with cottonwood the liability of total failure in securing reproduction is reduced. Another advantage is the beneficial effect of the other trees upon the cottonwood itself in shading the forest floor, thus preventing the

growth of vines and underbrush. They will also help to clear the cottonwood of side branches.

The most valuable associates of cottonwood are green and white ash, the various red and white oaks, and red gum. Only ash and oak command higher stumpage values. Red gum is now much less valuable on the stump, and, like the other associates, is much slower growing. Assuming a stumpage value of $5 per thousand for cottonwood, the following figures would be typical for its associates, if of good quality: red gum, $2; oak, $5 to $7; ash, $6 to $10; cypress, $5; elm, $2. The less important species, such as hackberry, sycamore, boxelder, river birch, and silver maple, usually have little, if any, value for lumber, although under certain conditions they may sometimes be worth from 50 cents to $1 for fuel, especially in the north of the valley.

The high value of ash makes it one of the most desirable species to encourage in the bottoms. Measurements in the northeastern section of Arkansas indicate that in comparison with cottonwood the greater value of ash timber is to a large extent offset by its much slower growth. Ash, however, is used in much smaller sizes than cottonwood, as in the manufacture of tool and implement handles and oars.

Red gum is more abundant and more extensively used for lumber in the South than is cottonwood. Its use is increasing, and it reproduces readily. Thus, although its present stumpage value is low and its growth much less rapid than that of cottonwood, it will often be advisable to encourage red gum in restocking logged-over areas.

The faster growing oaks, especially red and willow oak, are also of sufficient importance to encourage to a certain extent, particularly on the higher portions of the bottoms. They do not grow as fast as cottonwood, but produce more valuable wood.

SEED TREES.

As in pure cottonwood, a clear cutting system with provision for seed trees is the only means of securing reproduction of cottonwood in mixed stands. It is likewise adapted to the other valuable species, except oak. Red gum's intolerance of shade is probably exceeded among the bottomland species only by cottonwood itself. Ash when young will endure partial shade, but during most of its life full light is essential to rapid growth. The prolific regeneration of these three species on old fields and other openings where the mineral soil is exposed confirms the advisability of clear cutting.

The selection of seed trees in mixed stands should be governed by the same general considerations as in pure stands. Since all gum and oak trees bear seed, selection of seed trees is easy. Seed

of ash and gum are heavier than that of cottonwood, and therefore more seed trees are required per acre to insure dense restocking. Acorns can not be scattered for any distance by the wind, and therefore natural reproduction of oak can not readily be secured under a clear cutting system with seed trees. The best way to encourage oak in a cottonwood stand is to preserve young, thrifty immature trees wherever they occur. In swamping, or in cutting or deadening inferior species, the aim should be to save the oaks and free them from crowding. Besides forming part of the next cut, they will reproduce to some extent.

One cottonwood seed tree per acre will usually be adequate for seed purposes. Where either ash or gum are present the total number of seed trees per acre of all species should be from three to four. On cut-over areas completely in possession of weed trees it is useless to leave cottonwood to reproduce beneath thin shade. Here ash will sometimes meet the demand, since it will reproduce under moderate shade, but in its absence little can be done to keep boxelder, sycamore, hackberry, and other species of doubtful value from taking complete possession of the ground.

PREPARATION OF THE GROUND.

Preparation of the ground in mixed stands should be about the same as in pure stands. The shade in mixed stands is ordinarily more dense than that in stands of pure cottonwood. Consequently, there is likely to be less underbrush and vines, and slashing of undergrowth is correspondingly less troublesome.

In mixed stands, however, the problem is usually somewhat complicated by the presence of many inferior trees which have no merchantable value. Proper ground preparation in these stands will entail an outlay for removing or deadening these undesirable associates. Where conditions are favorable to cottonwood reproduction, it would hardly seem justifiable to leave scattered inferior species merely in the hope that within a few years they may acquire commercial importance. An expenditure of $2 or $3 at most per acre in deadening these trees should result in the establishment of a valuable young cottonwood stand, which otherwise might be indefinitely delayed.

Where, however, the unmerchantable species are very numerous the cost of deadening will often be prohibitive and the reproduction of cottonwood impracticable.

Deadening is often a questionable course, in that numerous dead trees scattered over an area afford breeding places for insects which might later prove injurious to sound trees. Moreover, there is no positive assurrance that satisfactory reproduction will follow. It

is, however, a very common method of clearing bottom lands in the Mississippi Valley for agricultural purposes. On areas subject to overflow cottonwood reproduction is almost certain to follow if seed trees are present. All said, however, deadening is probably preferable to leaving the inferior species where the owner is prepared to make an actual investment for the sake of insuring future cottonwood stands. Only the largest trees, such as could not readily be felled with several strokes of the ax, should be girdled. The cost of deadening, as well as swamping, piling, and burning of the smaller growth, can usually be kept within $2.50 per acre. On many areas from $1 to $2 would put the ground in good condition for cottonwood seeding. Where the cost exceeds $3 deadening will probably, as a rule, be considered inexpedient.

In this connection the question of brush disposal should also be considered. There seems to be no possibility at present of utilizing cottonwood tops in any practical manner. They make very little brush and decay quickly, even though left unlopped. Moreover, they may be carried away by high water. There will be little to gain, therefore, in burning the brush, either for the sake of fire protection or the encouragement of reproduction. However, where much undergrowth and small, inferior trees must be swamped out, it may often be advisable to pile such material with the tops and burn it when partly dry. In thick cane or grass, tops and other brush will burn, even if left scattered. If the ground is to be dragged to expose the mineral soil, piling would be advantageous.

COTTONWOOD-WILLOW STANDS.

Cottonwood and willow are usually associated only in comparatively young stands. Either cottonwood is crowded out by the willow during the first 20 years or it overtops and kills out the willow. If any willow is left at the time of logging, it should certainly be removed, since it is distinctly inferior for lumber. If it can not be disposed of for pulp wood, charcoal, or woodenware, for which uses it is well suited and frequently in considerable demand, it should be cut or girdled. If cottonwood is cut for pulp in young mixed stands, the willow should also be taken, and any adjacent stands of pure willow removed at the same time. Young willow is generally in demand for revetting the river banks and should be disposed of without difficulty.

CLOSER UTILIZATION.

Close utilization is the first step in the proper handling of cottonwood stands. Every tree that will make a merchantable log should be cut, stumps should be low, and the trees utilized as high as possible into the tops. High stumps are often left because the trees are cut at

a time when the water is up. Stumps are sometimes from 8 to 16 feet high. Wherever practicable no stumps should be left higher than 30 inches unless the butts are defective.

More material is wasted in tops. Small logs should not be left in the woods if they can be handled profitably. Such logs saw out little above the grade of No. 2 common, which usually sells f. o. b. at the mill for from $12 to $15 per thousand. On expensive logging operations the actual cost of delivering these logs at the mill and sawing them may so nearly approximate this price as to allow no profit. Most of the mills sawing cottonwood are now taking logs as small as 14 inches and under favorable logging conditions many concerns can utilize straight top logs comparatively free of knots as small as 12 inches at the top. Most of the mills sawing cottonwood which have a daily capacity of over 50,000 board feet are located in the larger towns along the river or at the edge of bottom lands, necessitating a long haul. Small portable mills located on the tract can often utilize with profit logs as small as 10 inches in diameter at the top. Although only one mill of this type was observed in the lower Mississippi Valley, it is probable that in the future the small mill may make possible a closer utilization of cottonwood. In the northern part of the valley mills frequently utilize to advantage logs even smaller.

Much of the present waste in leaving top logs is due, in part, to the improper marking of log lengths. Moreover, where logging is done by contract, a common method in the lower valley, the contractor leaves much small-sized timber in the woods, as by handling only the larger logs he reduces the cost of getting the logs to the river. The contracts should plainly specify that all trees above 16 inches diameter breasthigh that will cut one or more merchantable logs shall be taken unless designated for seed trees. Tops should be utilized to 12 inches where straight and free from branches, or to 14 inches where they contain no more than four or five small branches not over 4 inches in diameter.

To increase the percentage of cottonwood in future stands and gradually eliminate the less valuable species, the latter should be cut whenever possible, even without profit. Actual loss may at times be justified, since it may be considered an investment in restocking the area to cottonwood. As a rule, however, the removal of these "weed trees" will be warranted only where their utilization is possible. For this purpose the erection of cooperage plants on or near logging operations would materially simplify the problem. Such plants could utilize at a profit the larger elm, maple, hackberry, sycamore, and box-elder, as well as much of the cottonwood and gum too small for saw timber. Otherwise, deadening these trees would be the only means of clearing the ground for reproduction. The plants could also utilize a good proportion of the lumber which would ordinarily be left in the

tops. Where the size of logging operations does not warrant setting up such secondary plants, it will often be possible to barge the logs or bolts of the inferior species to hoop mills, excelsior factories, or cooperage plants located in the principal cities along the river. Even though the price received no more than covers the woods and transportation cost, the importance of encouraging cottonwood reproduction will often justify such a disposal.

Charcoal burning and wood distillation is another industry which, if it could be profitably conducted in these bottoms, would aid materially in close utilization. Practically every species could be utilized down to a diameter of 2 or 3 inches, including tops and limbs of felled trees. Maple, elm, sycamore, willow, birch, and hackberry should produce a good grade of charcoal, and be delivered at the pit for $2 per cord. The development of a market for small-sized material would have the additional advantage of making thinnings from young stands of cottonwood practicable. In many instances, however, the utilization of the poorer species will obviously be out of the question. A choice must then be made between leaving them until a market develops or deadening them.

THINNINGS.

The removal of a portion of the trees from a stand not fully mature is termed a thinning. Thinnings, if properly done at the right time, will result in accelerating the growth of the trees left, and at the same time utilize many of the smaller trees which would otherwise die from supression. A thinning will frequently pay for itself. Cottonwood responds in a marked degree to increased light. Its pronounced light requirement is in itself an unmistakable indication that thinnings will be beneficial. It is evident, further, that in cottonwood stands where in the course of natural development the average number of trees per acre falls from 700 to 50 between the ages of 10 and 40 years there must be great loss in growth rate due to competition.

Unfortunately, no example of systematic thinning in young cottonwood stands was found in the present study. On one plot, however, a good many of the trees had been removed in a rather haphazard and unsystematic manner, most of them apparently of the smaller sizes. The beneficial results of this chance opening up were, however, quite apparent. This particular stand was in southeastern Arkansas, and occupied good bottomland soil near the present course of the river. Its age was 17 years. It was stated that rivermen had been in the habit of drawing upon this stand from time to time for ship poles, barge braces, and the like. Cuttings were said to have been made for quite a number of years, although apparently none had been made very recently. Over most of the

area the stand had been opened up too severely, and toward the center many of the dominant trees appeared to have been taken along with the smaller ones. One half-acre plot was laid off, however, in which there was a fairly even distribution of the remaining trees, and from which the smaller or medium-sized trees were the ones chiefly removed. It happened that this small area was properly thinned. Table 7 shows the condition in this half-acre plot in contrast to the average for stands of this age.

TABLE 7.—*Effect of thinning on cottonwood stands.*

	Total number of trees per acre.	Trees per acre over 14 inches diameter, breasthigh.	Average diameter of all trees.	Average diameter of trees above 14 inches diameter, breasthigh.	Stand per acre.
			Inches.	*Inches.*	*Board feet.*
Average plot	215	34	10.5	15.5	4,000
Thinned plot	132	50	12.3	15.9	7,500

In the thinned plot there were approximately 40 per cent fewer trees per acre than in the average plot. Of trees over 14 inches in diameter, on the other hand, there were actually 47 per cent more, and the average diameter of all trees was 17 per cent larger in the thinned than in the average plot.

The results in this one thinned stand are corroborated by measurements of five 15-year-old plots of cottonwood across the river from Helena, Ark., in which was an understory of sycamore and a few other species, all more tolerant than cottonwood, and of the same age as the latter though only one-third the height. It was therefore apparent that the cottonwood started in mixture with the sycamore, but being of more rapid growth soon overtopped it, thereby freeing itself from crowding and side shade. Thus, while not actually thinned, it had passed through a natural stage in some respects closely paralleling artifical thinning. In these five plots the board-foot yield noticeably exceeds the average for the same age stands.

TABLE 8.—*Effect of associate species on form, growth, and yield of cottonwood.*

Age 15 years.	Total number of of trees per acre.	Number of trees per acre over 14 inches diameter breasthigh.	Average diameter of all trees.	Average diameter trees over 12 inches diameter, breast-high.	Yield per acre.
			Inches.	*Inches.*	*Board feet.*
Average of all plots	275	22	9.2	14.9	2,400
Average of 5 plots with sycamore understory	200	27.6	10.4	15.1	3,040

It is fair to assume that artificial thinning would be followed by somewhat similar results.

Economic conditions, such as markets for small material, extent of investment, etc., will govern to a large extent the practicability of thinnings. In the lower Mississippi Valley there is at present little if any demand for the small-sized material which thinnings would yield. Pulp companies, with mills in Indiana and Ohio, have frequently purchased peeled cordwood of small dimensions as far south as Memphis. If such companies find it profitable to establish plants in the lower valley where there are extensive areas covered with young willow and cottonwood, a market might be expected to develop rapidly for the products of thinnings. While in some instances this small material may now be disposed of for fuel, braces, small poles, etc., as a rule it can not be profitably marketed.

There is danger in making thinnings too heavy and so permitting the entrance of objectionable undergrowth. Unless there is an understory of a more tolerant tree, such as green ash, sycamore, hackberry, or silver maple, only very light thinnings are advisable. In such a case the slower growing trees clear the fast-growing cottonwoods of side branches, shade the ground, and prevent the starting of grass and undergrowth.

If the rotation of cottonwood for lumber production may easily be shortened at least five years by thinnings without diminishing the yield per acre, thinnings might in some instances be justified on financial grounds, even when yielding no direct return. The saving of five years' interest on the investment in land and taxes with interest would certainly justify, under some conditions, an investment in thinnings. For example, the cost of maturing a crop of cottonwood in 30 and 35 years would approximate $77.97 and $112.07, respectively. This represents a saving for 30-year-old stands of $34.10. It is not improbable that two thinnings at the ages of 10 and 18 years, respectively, might shorten the rotation, so as to result in practically the same yield at 30 years as it ordinarily requires 35 years to produce. The costs of such thinnings should not exceed $2 and $5 per acre, respectively, which compounded with interest at 7 per cent would represent an outlay of $19 at the end of the 30-year rotation. In other words, the investment in thinnings could be expected to return 7 per cent interest like the rest of the investment, provided it lowers the cost of the crop $19 by shortening the rotation. As a matter of fact, an additional profit of $15.10 would result in this case, represented by the difference between $34.10, the saving in the cost of the crop, and $19, the cost of the thinning. With a larger investment, as in the case of planting, the difference in favor of thinning would be still more pronounced. If the cost of

thinning could be partially or totally met by a market for the material removed, the possibility of increased returns would, of course, be still further improved. Until markets for small stock improve, however, or until more definite conclusions can be made respecting the actual increase in growth due to thinnings, it is doubtful if thinning operations will generally be considered feasible in natural stands of second-growth cottonwood in the South.

ROTATION.

LUMBER.

A rotation of approximately 35 years is sufficient to yield maximum returns from natural stands of pure cottonwood. This is based on present market requirements, and corresponds almost exactly to the age at which a stand has attained its maximum mean annual yield of 840 feet per acre board measure, the trees ranging from 10 to 30 inches in diameter, with an average of 19.7 inches (Table 3).

An average stumpage value of $5 per thousand feet at 35 years is assumed. Below this age, with present merchantable sizes, the stumpage value of cottonwood decreases very rapidly and few stands are now being cut much younger.

Since all forest investments are reckoned at compound interest, the latter necessarily has an important influence upon the length of rotation. This is shown from the following figures, which indicate the necessary increase in stumpage value to warrant extending the rotation beyond 35 years, at which age a stumpage of $5 per thousand is assumed. The investment is reckoned at 7 per cent for a 35-year period. An initial cost of $5 per acre is allowed for establishing the stand by natural reproduction, taxes are assessed at 20 mills on the dollar for a land valuation of $3 per acre, which is assumed to increase $1 each succeeding decade. The sale value or cost of the land is placed at $5 per acre.

Age.	Stumpage.
35	$5.00
40	6.73
45	9.60
50	13.88

Thus, in order to warrant lengthening the rotation from 35 to 40 years, the value of the timber per thousand feet must increase from $5 to $6.73 during this period. This merely means that a stumpage value of $5 per thousand at 35 years will return a net profit equivalent to a stumpage value of $6.73 per thousand at 40 years. At rotations of 45 and 50 years the stumpage value would have to attain $9.60 and

$13.88, respectively. Unless the owner were assured that the larger proportion of high grades cut from stands of these greater ages and consequently larger average dimensions would give the standing timber this large increase in value, he would not be justified in deferring the final cut.

A determination of the rotation necessarily involves some knowledge of the manner in which an increase in the size of logs affects the proportion of different grades that can be cut from a given stand. One or two concrete examples will probably make this clear. For instance, one millman kept a detailed record of the grades sawed from certain logs representing the yield of a heavily stocked stand in northwestern Mississippi cut clear in 1912. This stand was approximately 46 years old, and the logs for the most part ranged from 14 to 30 inches top diameter inside the bark. The following proportion of different grades, based on a two months' cut of nearly half a million feet, is believed to be fairly typical of normally stocked pure stands:

	Per cent.
Boxboards	9
Firsts and seconds	18
No. 1 common	30
No. 2 common	42
No. 3 common	1

In contrast to this is the actual mill tally for a run of unusually large logs from a stand supposed to be at least 90 years old. These high-grade logs ranged from 24 to 48 inches in diameter at the top and cut out approximately the following grades of lumber:

	Per cent.
Boxboards	7
Firsts and seconds	40
No. 1 common	35
No. 2 common	15
No. 3 common	3

This lumber was graded, moreover, in 1901, when grading rules were more rigid than at present. Under present grading rules a large proportion of this material would be put in the next higher grade. In the judgment of some millmen, timber of this quality would run now more nearly as follows:

	Per cent.
Boxboards	15
Firsts and seconds	43
No. 1 common	30
No. 2 common	10
No. 3 common	2

Unfortunately, no records of similar tallies for stands as young as 35 years were found. Several millmen of wide experience, however, gave estimates differing but very little on the probable proportion of grades that could be cut from logs ranging from 14 to 24

inches in diameter, such as could usually be obtained from well-stocked stands of this age. The following figures are believed to be representative of such stands:

	Per cent.
Boxboards	5
Firsts and seconds	18
No. 1 common	30
No. 2 common	47

Prices for various grades will, of course, vary with the locality, season, or year. The following prices, which were fairly typical for the different grades f. o. b. at the mill during the fall of 1912, are used as a basis to determine the relative log values for the several instances cited:

	Per thousand.
Boxboards	$44
Firsts and seconds	27
No. 1 common	21
No. 2 common	16
No. 3 common	12

Using these figures, the actual mill-run values per thousand feet for the instances cited are given in Table 9.

TABLE 9.—*Value of logs of different grades based on actual mill run.*

Age.	Range of logs, diameter inside bark.	Mill-run values per 1,000 feet.	Stumpage.
Years.	*Inches.*		
35	14–24	$20.88	$5.00
46	14–30	21.96	6.08
90	24–48	26.35	10.47

Assuming that logging and milling costs are the same for the three ages cited, it appears that stumpage values will be apt to increase a little more than $1 per thousand between the ages of 35 and 46 years. By comparing the stumpage values given on page 42 it is evident that one can not afford to hold the timber, since the cost increases four times more than the stumpage value. The time for cutting cottonwood stands established to-day must eventually be determined on the basis of future market conditions. From the present indications, however, a maximum of 35 years will be necessary for cottonwood grown for saw timber in natural unthinned stands. In stands established artificially the same yields can probably be obtained in much shorter time, for the regular spacing in such stands enables the young trees to attain in four or five years the dimensions of six or eight year old trees in dense natural thickets. Where thinnings are

possible the rotation can be further shortened. Planted stands which can be thinned once or twice during the rotation might easily reach maturity at least 5 or 6 years earlier than natural stands which have been given no special attention. If improved market conditions make it possible in the future to harvest unmanaged natural cottonwood forests in the Mississippi Valley in 30 years, it would be possible to cut well-managed, planted forests in 25 years or even less.

CORDWOOD.

In average natural stands of cottonwood cordwood can be obtained in about 16 years, with a total yield of approximately 42½ cords per acre, or an annual yield of 2.7 cords. Under particularly favorable conditions of growth the time may be shortened to 13 years. In planted stands the time may be reduced even to 12 years, especially where thinning and cultivation are possible.

Since stands cut for cordwood can be most easily renewed by coppicing, the second rotation should be much shorter than the first because of the more rapid growth of the sprouts.

No stands were found in this country to indicate the exact difference in the length of rotation for coppice and for seedling forest. In South America, where the coppice system is practiced on short rotations, wood of suitable dimensions for saw purposes is grown from cuttings in 10 years, and a second crop equal to the first is obtained by sprout reproduction in 7 years. In the case of natural stands renewed by sprout reproduction the difference between the lengths of the first and second rotations would be much greater than in the case just mentioned, where the first stand was obtained from cuttings, a form of sprout reproduction. Reproduction by coppicing in the Mississippi Valley therefore ought to make possible a second rotation as short as 10 to 12 years.

RETURNS FROM GROWING COTTONWOOD.

The returns from growing cottonwood will depend upon the manner of establishing the stand and the product desired.

LUMBER.

Where a cottonwood stand is to be established by natural reproduction, supplemented by planting, the following costs per acre may be taken as conservative:

Site preparation	$2.50
Seed trees	1.25
Planting one-third the area	1.25
Total	5.00

Where the stand is to be established wholly by planting the costs will be:

Preparation of the ground	$2.50
Cost of stock (8 by 8 feet)	1.00
Cost of planting	2.50
Filling in blanks	1.00
Total	7.00

The cost of the land will vary widely under different conditions, but at present $5 per acre will be the average price of unprotected land unsuitable for farming. Such lands are usually valued for taxation purposes at only $1 to $3, and are seldom taxed more than two cents on the dollar. Some allowance for increased taxes in the future should, however, be made. The present land valuation for tax purposes is therefore placed at $3, and an increase of $1 per acre allowed for each succeeding decade.

It is a fair assumption that a stand established by natural reproduction, supplemented by planting one-third of the area, will yield at least three-fourths as much as the fully stocked stands shown in Table 3. On the basis of these figures such a stand would, if the stumpage is worth $5 per thousand board feet, return 7 per cent on the investment, with a rotation of about 35 years.

A planted stand, fully stocked, even though the cost of establishing it may be higher than in the case of a stand secured by natural reproduction, should return about 7.3 per cent, because of its greater yield per acre.

While on the whole at least 6 or 7 per cent can be expected from growing cottonwood, the profitableness of the undertaking must be determined for each particular case by a careful study of local conditions.

CORDWOOD.

The present low stumpage value of cordwood makes it a questionable policy to sacrifice thrifty young cottonwood brakes for this use. Such stands, if established in the same manner and at the same cost as described for saw timber, will show a return of scarcely 6 per cent. This requires a fully stocked stand over the entire area, which can scarcely be secured except by planting. With only three-fourths of a normal yield per acre, as figured for saw timber, the investment would not net more than 4 per cent. If natural reproduction, supplemented by planting, would result in a fully stocked stand, the returns may be increased to 5 per cent.

To make the growing of cottonwood for pulp as profitable as for saw timber, the stumpage must bring from 80 to 90 cents per cord,

The possibility of pulp companies growing cottonwood near their plants is of special interest. It does not seem unlikely that the much higher stumpage value of pulp wood located within hauling or short shipping distance of such mills may even justify the use of fairly good farm land for this purpose. For example, if a company, by cultivation, thinning, etc., could raise a crop of cottonwood in 12 years, with a yield of 47 cords per acre, worth $2 per cord on the stump, it might be feasible to invest as much as $50 per acre in land, provided it were rich, moist, but well-drained bottom land naturally adapted to the tree. Land as expensive as this would be already cleared. It could be put into condition for planting by plowing, etc., for $2 per acre. Assuming that 6 per cent return would satisfy a company growing its own pulpwood, the following outlay per acre would be adequate:[1]

Interest on cost of land at $50, 12 years, at 6 per cent	$50.61
Initial outlay (stock $1.50, planting $2.50, soil preparation, $2), $6, 12 years, at 6 per cent	12.07
Taxes (2 per cent on one-half value), 50 cents per year, 12 years, at 6 per cent	8.43
Thinning at eight years, $2, four years, at 6 per cent	2.52
Cultivation, $4 per year first two years	15.64
	89.27

The gross returns would be represented by 47 cords of pulp wood at $2 per cord, or $94.

The crop would be renewed by stump sprouts at practically no cost, except cutting back all but the best sprout on each stump during the summer after felling. This should not exceed $2 per acre. Cultivation would be necessary, since the renewed stand would be only half as dense. Because of the more branchy growth pruning would doubtless be needed after 3 or 4 years, but no thinning would be required. A 10-year rotation would probably be ample for this coppice growth, so that the new crop could easily return 8 per cent, as shown by the following costs and returns per acre:

Interest on cost of land, at $50, 10 years at 8 per cent	$57.95
Cutting off sprouts, $2, 10 years, at 8 per cent	4.32
Taxes (2 per cent on one-half valuation), 50 cents, 10 years at 8 per cent	7.24
Cultivation, $4 per year for first two years at 8 per cent	16.63
Pruning when 4 years old, $5 at 8 per cent	7.93
Total	94.07
Gross returns, 47 cords pulp wood at $2	94.00

[1] No filling in of blanks will be necessary because of the close planting and thorough prepartion of the ground.

PLANTING.

ADVISABILITY.

Wherever fully stocked stands can be secured by natural reproduction no planting need be done. Where seed trees of cottonwood are wanting, on low-lying areas where water stands late in the spring, and on areas where young seedlings might be choked out by vines, briers, or low underbrush, it will be necessary to supplement natural reproduction with planting. Without planting, many portions of the logged-off areas would be only indifferently restocked, while in some places reproduction would be entirely lacking.

Planting, however, is not limited to the restocking of cut-over bottom lands. A tree of such rapid growth and value as cottonwood will no doubt be introduced into localities where it is not now found naturally. The present local occurrence of cottonwood does not necessarily coincide with the areas where it might be expected to make good growth. The fact that this species is seldom found growing naturally far from streams or moist bottom lands is the result of the failure of its seed to germinate satisfactorily on any but moist exposed mineral soils, such as are provided by the deposits from spring floods. This difficulty, however, is avoided by planting young trees. When the roots of the planted stock penetrate to a moist subsoil the tree displays its usual rapid development.

Carolina poplar and Norway poplar are extensively advertised by nurserymen as superior to the common cottonwood for rapid growth in forest plantations. The three trees are all closely related. Differences in leaf and growth characteristics are often urged as grounds for considering Carolina poplar and cottonwood as distinct species. Carolina poplar itself, however, shows widely varying characteristics in different sections of the country, and often can not be distinguished from cottonwood. The differences between Norway poplar and cottonwood are equally vague. Both Norway and Carolina poplar are male trees propagated entirely from cuttings, and it is believed that both are derived from staminate trees of our common cottonwood. It has already been pointed out that cottonwood has been commonly planted in Europe, where certain nurserymen claim to have developed exceptionally rapid growers. Possibly our Norway poplar may have originated in some such way, or it may have been taken originally from some of these rapid-growing European forms. It is not at all certain, however, whether it really exceeds our native cottonwood or the Carolina poplar in growth. Indications are that in the north cuttings from thrifty Carolina or Norway poplar may develop more rapidly than cottonwood. In fact, it is generally believed that the male trees are more vigorous growers than the female. Another merit claimed for Norway poplar in com-

FIG. 1.—COTTONWOOD SHELTERBELT 10 YEARS OLD, SOUTHERN MINNESOTA.

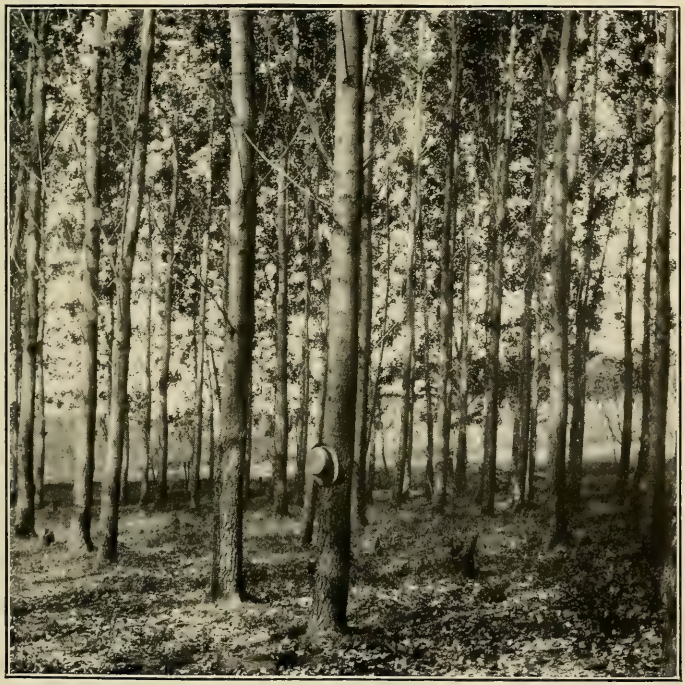


FIG. 2.—INTERIOR OF FARM GROVE OF COTTONWOOD 12 YEARS OLD, SOUTHERN MINNESOTA.

FIG. 1.—GERMAN PLANTATION OF COTTONWOOD 5 YEARS OLD, SHOWING WIDE SPACING, 12 FEET BY 15 FEET, AND RESULT OF HEAVY PRUNING.

FIG. 2.—AMERICAN PLANTATION OF COTTONWOOD 4 YEARS OLD, CLOSELY SPACED, 4.5 FEET BY 9 FEET, AND IN NEED OF THINNING.

parison with other poplars is that it forms a better shaped stem, freer of side branches. Such conclusions are based on a comparatively small number of plantations in southern Minnesota, which hardly afford sufficient grounds for recommending this tree in preference to the better known cottonwood or the Carolina poplar.

PLANTING SITES.

Moderately well-drained, permeable bottom lands afford the best planting sites. The soil need not be rich or loamy. Very sandy land will be suitable if the water table is within from 12 to 15 feet of the surface. Even upland sites may sometimes be suitable, provided the soil is not too shallow and rainfall is abundant and well distributed. Suitable upland sites, however, are apt to be well adapted for farming.

COMMERCIAL PLANTING.

The cottonwood lumber industry is almost exclusively confined to the Mississippi Valley, where maximum returns can be obtained on a 35-year rotation, or in the central and southern sections perhaps on as short a rotation as 25 to 30 years. Even in the north, where the growth of cottonwood is comparatively slow, the better market for small sizes will make it possible to produce saw timber in 35 to 40 years. For the present, however, planting for lumber should probably be restricted to the central region.

The Northeastern and Central States offer another opportunity for realizing profitable returns from cottonwood plantations located close to pulp mills. Several pulp-manufacturing companies have already started plantations of cottonwood.

Black cottonwood (*Populus trichocarpa* Torr and Gr.), which is very similar to the cottonwood of the Mississippi Valley, has been planted to some extent for pulpwood in western Oregon and Washington. The success already attained with this species emphasizes the possibilities of our eastern cottonwood in the region. The common cottonwood should do well in the Pacific Coast States, where the markets for pulpwood and box material should afford a ready outlet for the products of plantations. It is not certain, however, that *Populus deltoides* will excel in any respect the native *Populus trichocarpa.*

PLANTING FOR WINDBREAKS.

Cottonwood plantations are often warranted where, as in Iowa, Minnesota, the Dakotas, Kansas, and Nebraska, timber for lumber, posts, and fuel is scarce. Plantations of cottonwood made by the pioneers in those States from 30 to 50 years ago, often on dry upland sites, have in many instances been sawed up into rough lumber at

a decided profit. Commercial planting in this region, however, should be restricted to bottom lands, or, in the case of windbreaks, to good farm land. (See Pl. V, fig. 1.)

The possibility of combining timber growing with windbreak planting opens up an important field for cottonwood in the Middle West on farm lands too valuable to permit of timber production for its own sake. One of the chief requisites in a windbreak tree is rapid height growth. Cottonwood meets the requirement better than any other species. It is adapted to any good, moist situation, such as river bottoms, or even typical farm land of the rolling uplands of the eastern portion of the region, where rainfall is comparatively heavy. On dry situations, where long droughts are common, a less exacting tree is better.

There is, however, a serious objection to cottonwood for windbreaks, due to the sapping effect of its roots upon adjoining crops. It is generally considered more injurious in this respect than any other tree used for windbreaks in this region, and many farmers are cutting down groves or belts of cottonwood with no intention of replanting it. As a matter of fact, however, actual measurements made by the Forest Service show conclusively that in comparison to its height cottonwood is the least injurious of any species commonly used.[1]

The sapping effect of cottonwood, as of any other tree used for windbreaks in the Middle West, is almost always more than offset by the increased crop yield on the fields protected. Windbreaks in this region will usually more than repay the rental for the actual area of valuable farm land which they occupy without even taking into account the direct financial returns from marketing the wood product.

Since the tree's foliage is rather open, cottonwood windbreaks should be underplanted with a shade-enduring species either as soon as the stand begins to open up or else at the outset. For this purpose any one of the following trees will do: white or green ash, red oak, box-elder, and silver maple. Another method of overcoming this difficulty would be to plant only two or three rows of cottonwood the first year, and to plant additional rows on the side most exposed to the sunlight as soon as the original trees show a tendency to become open. Two hundred and forty feet has been recommended as the most suitable width for a windbreak belt of cottonwood in this region.

PREPARATION OF SITE.

Planting without a thorough preparation of the site is inadvisable. On freshly cut-over land the preparation should be practically the same as for natural reproduction. Full sunlight is equally indis-

[1] Forest Service Bulletin 86, "Windbreaks."

pensable both for natural grown and planted cottonwood. Planting on heavy sod is never advisable. If plantations are to be established on improved farm land for windbreaks, it will be of advantage to plow and harrow the ground. Plowing will cost not more than $2 per acre. The higher stumpage values of cottonwood on the prairie farms of the Central West, from $10 to $12 per thousand feet, will, moreover, warrant this more intensive preparation.

On cut-over bottoms cultivation of the ground preparatory to planting is usually not justified from a financial standpoint, nor is it essential, since the amount of moisture is so much greater and rich alluvial sediment is deposited every year by spring overflows. On bottom lands cleared for farming, however, cultivation is as advantageous as on the uplands.

There is another type of bottom land which, though not growing up to trees or underbrush, is nevertheless so completely covered with tall, thick, dense-growing weeds, principally horseweed in the North and indigo plant and cocklebur farther south, that planting without first preparing the ground is out of the question. Abandoned fields and old filled-in river beds and lake bottoms are typical of this kind of land. These weeds on such land are sometimes 10 or more feet high. They can not readily be plowed under unless they are first broken down so as to lie with the furrows. This can be done by hitching a team to each end of a 30-foot log and rolling it over the weeds, breaking them off close to the ground. This must be done in the fall, when the stems are stiff and dry and snap off easily. The cost of clearing and plowing such land should rarely exceed $2.50 per acre.

The thoroughness with which the ground is to be prepared must depend, of course, on the returns to be expected. As a rule, these can be placed at 7 per cent. Assuming a rotation of 35 years, with a yield of 29,400 feet board measure, worth $5 per thousand on the stump, the total gross returns would be $147 per acre. The interest for 35 years on an assumed land value of $5 amounts to $48.38; taxes based on a valuation of $3 now and an increasing value of $1 for each successive 10-year period will represent an investment of $10.31 at a tax rate of 2 cents on the dollar. Assuming the initial cost of stock and planting at $4 per acre, or $42.71 in 35 years, the total investment with interest at 7 per cent less the cost of preparation will be $101.40. This leaves $45.60 available for the cost of preparation, including interest. In other words, approximately $4.25 per acre can safely be invested in preparing the site. If it is unnecessary to expend the whole of this, the net annual return will be proportionately increased. On the other hand, if this amount is insufficient to give adequate preparation, the other items of expense must be reduced, or else the owner will not receive his 7 per cent.

METHODS OF PLANTING.

In planting cottonwood either cuttings or wild-grown seedlings have been largely used. Although growing seedlings in nursery beds and transplanting them out when they are a year old is the method usually recommended for most trees, yet in the case of cottonwood, because of the difficulty of handling the seed and the simplicity of the first two methods mentioned, nursery practice is less practicable. Reforestation by direct seeding over the area to be stocked will, as a rule, also be impracticable.

WILD SEEDLINGS.

An abundance of 1-year-old wild seedlings can in most years be found in dense thickets on overflow lands along the Mississippi River and its tributaries. If these are collected, only the best should be straggling root system is decided contrast to the stocky, fleshy, coming on coarse sand. The latter are very apt to have a rather long, straggling root system in decided contrast to the stocky, fleshy, compact roots characteristic of trees growing in rich moist soil. Not only will this latter stock prove more vigorous, but it will be much easier to handle. It should not, however, be transplanted to exceptionally dry sites. One-year-old trees are usually the best, except when they have to compete with weeds and grass. Older trees are apt to be so large that they are expensive to handle. The wild seedlings should be taken up before they have begun to grow in the spring. If possible, they should be collected after a heavy rain, when they can be pulled out without injury to the roots. They may be dug up with a spade, but a better method is to turn the surface soil with a plow. Stock can sometimes be collected in this manner as cheaply as 50 cents per thousand, and should seldom cost $1. Wild seedlings can generally be purchased from nurserymen or collectors for from $1.50 to $2.50 per thousand. It is advisable in purchasing collected seedlings to make sure they come from a region of similar climatic conditions.

NURSERY SEEDLINGS.

Nursery-grown seedlings are seldom used in the establishment of cottonwood plantations. On dry sites, however, the superiority of seedlings over plain cuttings is unquestioned. Although nursery practice with cottonwood in this country is still in its infancy, a fairly good stand of young seedlings may be obtained in nursery beds at a very low cost. In fact, where rooted stock is essential and wild seedlings are not available, nursery seedlings can be produced at less expense than rooted cuttings.

Cottonwood matures its seed in the south as early as the last of April or first of May, while in the latitude of Minnesota seed may

often be obtained up to the second week in June. Abundant seed is produced annually. The seed should be collected just before the pods or capsules begin to open, although large quantities of it could easily be obtained later in protected places on the ground. Seed collected from the ground, however, is apt to be mixed with other material such as leaf litter or even with seeds of other species, particularly of willow, which also mature early. Furthermore, ground-collected seed is obviously not so fresh as that in the unopened capsules; this, because of the short vitality of cottonwood seed, is a disadvantage. In the case of large open-grown trees, the catkins may easily be picked from the tree by a man with a ladder. Where logging operations are in progress at this season seed can be obtained from felled trees at a very low cost. It is also frequently possible to obtain plenty of green catkins of good quality which have been blown off the trees by heavy winds just before opening. As a rule, however, the picked seeds are more dependable.

The green "seed balls" should be kept well aerated. If stacked in large piles or kept in closed receptacles there is danger of their becoming heated and possibly losing their vitality. They should, therefore, be spread out to dry as soon as collected, and when they begin to open should be covered over with strips of paper to prevent the cottony seed from escaping into the air. As soon as the capsules are wide open the seeds are ready for sowing. The vitality of the seed lasts for only a week or two at the most.

The nursery bed may be prepared in the same manner as for any other broadleaf species. The soil should be deep, moist, and permeable. It should be well worked to the depth of about a foot. Sandy soils should be enriched and well mixed with manure. The surface of the beds, after being thoroughly worked, should be rolled smooth.

The seed balls may be spread out on the surface of the prepared nursery bed as soon as they have been collected, and thus allowed to dry out in the sun until the pods are opened sufficiently to shed the seed. Best results can be obtained by collecting small branches bearing a good supply of seed catkins and laying them on the beds with the catkins still on them. As soon as the seed balls open the seed can readily be shaken out over the surface of the bed, after which it should be soaked down and lightly covered with a sprinkling of sand. After the pods have begun to open it may be necessary to keep the beds covered with strips of heavy paper in order to prevent the escape of the "cotton." The seed must be shaken out over the bed on a very calm day, or else beneath the paper cover.

If the seed balls have dried previous to sowing, the seed should be spread as evenly as possible over the surface of the bed until it is entirely covered with a very thin layer of cotton. Over this dry

soil should be evenly sifted until the cotton is just hidden from view. The bed should then be thoroughly saturated with a light spray of water. The surface moisture can be preserved by covering the bed as soon as sown with paper strips, which, however, should be removed as soon as the seedlings begin to appear. The seed beds should be watered from time to time as necessary.

Still another method which has been reported as successful is carefully to mix the seeds, which have been allowed to open in paper bags, with moist soil, which prevents their blowing away, and sow the mixture of soil and seeds evenly over the bed and cover very lightly. Care must be exercised not to cover the seeds too deep—not over an eighth of an inch, or barely enough to hide them from view.

Except when the branches of green catkins are spread over the bed, it is well to drench the soil thoroughly before sowing the seed. It is of great importance not to let the surface become dry before the seedlings have developed fairly deep roots.

The seed may be either broadcasted or sown in drills or rows. When the seed capsules are allowed to open on the bed, however, the latter method will be impracticable. Broadcasting is apt to result in overcrowding, and so in spindling weak stock. In broadcasting, therefore, the seed should be sown sparingly, only a very thin layer of cotton being spread over the surface of the bed. If the stand is too dense it should be thinned. Fifteen to 20 trees per square foot is a sufficiently dense stand at the end of the first growing season. If the seed is sown in drills the beds can be more easily weeded and cultivated. Broadcasting, on the other hand, permits fewer weeds to start. The trees in the rows have plenty of side room for development, and are therefore more stocky and vigorous. On heavy soils, where alternate freezing and thawing during the winter is likely to injure a good many of the seedlings by gradually lifting them from the ground, the rows of trees can be better protected than the broadcasted beds by spreading a thick covering of straw over the ground between the rows. Thinning may often be necessary even in drill-sown beds, for the seedlings should not stand closer than 2 inches in the row, which will allow 18 trees per square foot, with 4-inch intervals between the rows.

By fall nursery-grown seedlings should reach a height of at least 2 feet. They will be ready for taking up and planting early in the spring as soon as the frost is out of the ground, or, where fall planting is practicable, as soon as growth ceases in the fall.

TREATMENT OF SEEDLINGS BEFORE PLANTING.

Methods of handling seedling stock preliminary to planting are the same for both nursery-grown and wild-grown trees. Above all, the roots should not be allowed to dry out before planting. The

seedlings may be bundled together in bunches of fifty or a hundred and the roots covered with wet burlap or wet sphagnum moss. The tap-roots of vigorous seedlings may often be too long to handle easily. In such cases they should be cut with a sharp knife 12 inches or less below the root collar. If they can not be planted for several days they should be "heeled in" in a trench deep enough to bury the roots and part of the stems. The trench should run east and west, with its south bank somewhat sloping. The bundles of trees should then be placed side by side in the trench on its sloping side, their tops toward the south, and their roots and stems covered 2 or 3 inches deep with fresh earth dug from the opposite side of the trench. A second layer of trees should then be put in and covered as before, and the process repeated until all the trees have been heeled in.

CUTTINGS.

Cuttings are used in establishing most cottonwood plantations. The quality of cuttings depends very largely on the character of the parent stock, since a cutting will display essentially the same growth characteristics. Cuttings for planting in the central or southern part of the valley should be obtained from that region rather than from the far north. Cuttings from trees in regions of low rainfall, such as the valley bottoms of Nebraska or Kansas, would not be as suitable for planting in the Ohio Valley region as stock obtained from the central Mississippi Valley. Again, if planting is to be done on good bottomland soils, the cuttings should not come from ornamental trees growing on comparatively upland situations. Particularly where cutting stock is purchased from commercial nurseries, the planter should make sure that the parent trees are of the right kind.

The best cuttings are obtained from vigorous growing trees, preferably from the branches near the top. It may sometimes be possible to obtain cuttings of good quality from trees which are removed in a thinning, provided, of course, only the more thrifty intermediate trees are used for the purpose. Cuttings taken from the current year's growth are superior to those from older parts of the branch. Two-year-old wood, however, will usually be found entirely satisfactory, but wood older than this should not be used. Root cuttings are vigorous, but are difficult to obtain.

A convenient length for cuttings is about 18 inches, although under certain conditions the length may range from 10 to 36 inches. They should be made immediately after the tree is felled, in order to prevent the drying out of the twigs. In making them it is preferable to cut the twig off at a slant of about 45° with a thin-bladed, sharp knife. In this way one avoids crushing the stem or loosening the bark. Care should be exercised that none of the buds from which

the young sprouts later take their origin are rubbed off or injured. Liability to such injury can be largely reduced by tying the cuttings into bundles of any convenient size, which will also facilitate their counting. The tops should all be laid in the same direction, in order to facilitate planting. Although cuttings will sometimes grow when planted top downward, their growth in this position is not thrifty.

TREATMENT BEFORE PLANTING.

Cuttings are set out either plain or rooted. Plain cuttings may be set out either fresh or callused. A fresh cutting, however, is not so well equipped to establish itself in a slightly unfavorable new environment as is a young seedling whose roots can at once absorb nourishment. The cutting must first heal over the cut surfaces, which it does by forming a callus. It is then prepared to send out new roots, usually from this callused surface, but often also from points along the stem. During this period of adaptation and root formation suitable moisture conditions are essential. The soil should be well drained, permeable, and moderately warm. Weeds, grass, or brush should be kept down.

On the more unfavorable sites it is advisable to use callused cuttings, or even rooted stock. Callused cuttings have the cut surface healed over prior to planting, and are produced by burying bundles of cuttings in moist sand. If they are made in the fall and buried outdoors, the sand should cover them to a depth of about 2 feet to keep them moist and protect them from freezing. The surface soil should be protected with a covering of straw or leaves. Another good method consists of packing the bundles in boxes of moist sand which are stored in a cool room or cellar not subject to freezing. Stock kept in this way over winter should be in prime condition for early spring planting. If the cuttings are not prepared till spring, they should not be buried so deeply. At this season of the year the formation of the callus can be more quickly induced by selecting a spot with a southern exposure and a mellow, porous, and moist soil. The cuttings, bundled as before, should be buried with the large end within an inch or two of the surface. After 2 or 3 weeks, provided the ground is kept uniformly moist, the warmth of the soil will stimulate the healing of the cut surface. Where cuttings are set in nursery rows for the summer this treatment will considerably increase the percentage surviving at the end of the season. In burying the cuttings the buds must not be damaged.

On rather dry surface soils or where the young stock must grow rapidly to keep above weeds it is unwise to use any but rooted stock. One-year-old seedlings meet the requirement, but rooted cuttings will also prove valuable and may sometimes be superior to seedlings because of greater height. These are merely cuttings that have been

temporarily set in nursery beds, where they have developed roots and tops. The soil in the nursery should, if possible, be permeable and somewhat sandy. The ground should be prepared in the same manner as for a seed bed and the cuttings set to a depth of about 9 inches. If planted too deeply it will be difficult to take them up without injury to the roots, many of which form at the callused surface. In developing rooted cuttings, therefore, comparatively short sections are preferable, about 10 to 12 inches long. Not over 2 or 3 inches of the stem will protrude above the ground surface, but on this section there should be at least one good bud from which the new growth may spring.

The fresh or plain cuttings may be set in the nursery by preparing holes with a small stick or an iron bar, the holes to be slightly smaller in diameter than the cuttings themselves. If the soil is sufficiently soft and light, holes will not be necessary. If the cuttings are set at an angle with the ground, the soil may be more firmly packed by the foot. With this method there is danger that the roots will be cut when the stock is taken up from the nursery. A spacing of about 6 inches in the row and 1 foot between the rows will give the cuttings plenty of room for vigorous development and at the same time allow of hand cultivation. If there is plenty of available ground for the beds, a spacing of 2½ feet between the rows will be preferable, since it permits the use of a one-horse cultivator.

Since the growth of cuttings in the nursery is usually vigorous, it will scarcely ever be advisable to leave them there more than one summer, lest the root system becomes too extensive to handle easily in planting. A comparatively small, stocky, but vigorous root system develops where the soil of the nursery site is kept fairly moist throughout the growing season. The stock should be watered during drought. The cuttings may be taken up and planted on the permanent site the following spring, or, in the southern part of the valley, as soon as growth ceases in the fall, when they should be from 3 to 6 feet high.

SEED.

The difficulties of sowing cottonwood seed in the field render this method of little practical value. The light, buoyant, cottony seeds make it almost impossible to keep them where sown except during a dead calm. Even after sowing a large proportion of the seed will be blown away unless held down by the moist ground or by rain.

Seedspot sowing consists of placing several seeds at regularly spaced intervals rather than sowing over the entire area. So far as known this method has never been tried, and, like broadcast sowing, it is considered of little practical value. The only possibility of its use with cottonwood would be on wet situations, where a slight cover-

ing of soil would insure keeping the seed moist. The labor, however, would not be materially less than setting cuttings, while the chance of failure would be much greater.

COMPARATIVE MERITS OF DIFFERENT METHODS.

The use of fresh cuttings has the one advantage of cheapness. Such stock can easily be prepared for 75 cents per thousand. It is, however, the least thrifty of all planting stock. Its chief use is for planting on cultivated soil, as for farm woodlots or windbreaks, or on low sand bars with the water table within a few feet of the surface. Callused cuttings are slightly more expensive than fresh ones. The best quality of callused cuttings, made in the fall and stored in sand over winter, should not cost over $1 to $1.50 per thousand. They should do well on moderately dry soils or where there are some weeds, but not too many. Callused cuttings planted during the winter or early spring in the southern Mississippi bottoms will usually be rooted and will have started top growth before being covered by the spring floods. For this reason floods will not injure them greatly. Under such conditions fresh cuttings might not be sufficiently established to resist injury, and if completely submerged for a long period would probably be killed. Sometimes untrimmed branches, 4 to 5 feet long, are used as cuttings in order that the water may not entirely cover them.

For general planting in the overflow bottoms rooted stock will usually be superior to plain cuttings. It is better able to withstand adverse conditions, and even if killed back by rodents or by fire it will be likely to send up new shoots from below the injured portion. Wild seedlings will generally be employed because of their cheapness and availability. The cost of collecting them should seldom exceed $1 to $1.50 per thousand, or the same as for callused cuttings. Such stock is but little injured by complete submergence, remaining in good condition for weeks under water. They are ready to start height growth as soon as planted, which is a valuable characteristic in situations where weeds are likely to spring up.

Nursery seedlings have all the advantages of wild stock, except cheapness. A conservative estimate of the cost of propagating nursery stock is from $2 to $3 a thousand.

Cost is the principal objection to rooted cuttings. Their value for planting lies in their greater height than one-year-old seedlings combined with a vigorous, bushy root system. They are especially adapted to dry situations or where they are likely to come into competition with weeds. Their cost should not exceed $4 to $5 per thousand, and if grown on a large scale—as many as 50,000 to 100,000 at a time—it ought to be considerably less.

FIELD PRACTICE.

METHODS.

Cottonwood seedlings possess a long, thick taproot, with a few short, fibrous laterals. Methods of field planting will differ little with seedlings or cuttings. One of the best tools for setting either kind of stock is a long, narrow-bladed spade, with a sharp cutting edge, which can be inserted at least 12 inches into the ground. The blade need not be over 4 to 6 inches wide, but should have a foot extension for forcing it more easily into the ground, and a cross-bar handle to turn in making the hole. The soil can readily be filled in about the plant by forcing the earth from the outside by several insertions of the spade and finally firmed down about the plant with the foot. To facilitate the work a boy should insert the tree in the opening and hold it in place, while a man firms the earth about it. The boy also carries the basket of cuttings or seedlings. Seedlings should be set slightly lower than they stood in the nursery bed. Cuttings should be inserted about a foot deep. In cultivated soil, where short cuttings are practicable, they should be buried for their whole length, with the exception of 3 or 4 inches of top bearing the bud, and may be set at an angle of nearly 45° with the surface in order to facilitate packing the earth about them.

A plain pointed iron bar will often serve for planting cuttings. This may be improved by attaching a cross handle and foot bar similar to those described for the spade. A very satisfactory planting tool of this character can be made of iron gas pipe, with the lower end brought to a sharp point of specially hard temper.

COST.

By working 10 hours a day a man and boy should be able, after a little experience, to set out 1½ acres of seedlings or 2 acres of cuttings per day, which would amount to from 1,020 to 1,360 trees, if spaced 8 feet apart each way. Proper alignment of the rows can be gained by using flags or stakes, by which one man in each crew can line himself in. Assuming that two men plant an acre and a half per day, and allowing a wage of $2 for the man and $1.25 a day for his assistant, the total cost of planting should not exceed $2.50 per acre.

In the case of cuttings, which are easier to handle, this cost may fall below $2 per acre. If a closer spacing is adopted the cost will be proportionately increased.

Some rather large planting operations with cottonwood have been reported in which the total cost per acre, including cost of stock, preparation of site, and planting, with a spacing of 6 by 6 feet, was only $5 a thousand for seedlings and $3 for cuttings. The planting stock in this case was collected by the company in the vicinity of the planting.

TIME TO PLANT.

Spring planting is recommended. In the Northern States, in particular, fall or winter planting is likely to meet with poor success. The alternate freezing and thawing of the ground during the winter will often lift the plants entirely out of the ground. This applies equally to cuttings and seedlings. On light, sandy soil, however, this danger is comparatively small. In the south of the valley the danger of frost heaving is slight, and if planting is not done on very heavy soils there are advantages in planting during late fall or winter. Seedlings planted early in the fall will recover from any root injuries and become well established before spring. In fact, stock planted early in the fall will continue root activity well into the winter, and therefore will begin growth early in the spring. This will enable it to withstand better the spring overflow, which in the South is apt to occur within 4 or 5 weeks after vegetation begins. Furthermore, autumn planting is better in localities subject to prolonged drought in the spring. In general, however, fall planting, at least for the present, should be restricted to rooted stock, as it is still uncertain how well plain cuttings would withstand long exposure throughout the winter and overflow in late spring.

PURE VERSUS MIXED PLANTING.

Cottonwood may be planted either pure or in mixture with other species. An advantage of pure plantations consists in the greater simplicity of field planting and its consequent lower cost, especially since cottonwood stock is usually cheaper than that of any other hardwood tree that might be used in mixture with it. Pure plantations yield a larger quantity of solid wood on a short rotation.

The advantages which may possibly result from mixed plantations are a possible increase in the board-foot yield; an improvement in the quality of the timber, due to clearing cottonwood of its branches; and in shading the ground. Mixed planting is particularly of advantage in the establishment of windbreaks, for which cottonwood, as it matures, becomes too open to be thoroughly effective.

The associate species ordinarily would have no value, except possibly for cordwood. It would act chiefly as a "filler" to improve the quantity or quality of the cottonwood. Any of the following species would make suitable fillers: Silver maple (*Acer saccharinum* Linn.), boxelder (*Acer negundo* Linn.), sycamore (*Platanus occidentalis* Linn.), white ash (*Fraxinus americana* Linn.), and green ash (*Fraxinus pennsylvanica* Marsh). Probably the silver maple will be the most suitable species. One-year-old maple seedlings can be purchased from dealers for $2 to $3 a thousand. If a filler is

used, it should be planted with the cottonwood in the proportion of 3 to 1, with a row of the fillers alternating with a row in which every other tree is a cottonwood.

SPACING.

Where pulpwood production on a short rotation is desired, an initial spacing of 8 by 8 feet will give the best results. This will serve to clear the branches early and will allow one thinning where it may be financially justifiable.

For timber a spacing of 10 by 10 feet on the richest bottom lands is not too wide for the best growth of cottonwood. Thinning operations with such spacing could be deferred for a long time, as they would be of little advantage before the age of 12 to 15 years.

The readiness with which cottonwood thins itself naturally makes wider spacing than this inadvisable, and on average soils a spacing of 9 by 9 feet may be best. On comparatively dry soils a spacing as close even as 6 by 6 or 7 by 7 feet may sometimes be justified.

A general spacing of 6 by 6 feet, in which the cottonwood is set 12 feet apart each way and the intermediate spots are planted with a filler, is probably the best for mixed plantations. In such spacing every other row would contain only trees of the species used as a filler, while the intermediate rows would consist of cottonwood alternating with the filler. This would give a stand of about 300 cottonwoods to the acre, which is a normally dense stand between the ages of 14 and 15 years. Therefore, no thinnings would be needed before the plantation had become from 15 to 20 years old, when much of the material removed would probably be marketable for pulpwood, excelsior, etc. If the original planting were 8 by 8 feet, with the cottonwoods 16 by 16, the stand would not become much overcrowded during a rotation of 25 years. In the latter case, however, less provision would be made for trees injured or killed, and the timber would probably be less perfectly cleared of its side branches

SUMMARY.

Cottonwood is perhaps the most important tree in the Mississippi Valley, and may be expected to play a large part in the future production of lumber, veneer, and pulp wood. It grows rapidly, and can be cut for pulp wood when 15 years old and for timber and veneer in 35 years. To the owner of unprotected bottom land, lumber and pulp companies, therefore, it should appeal as a profitable tree to grow in the region, especially on the extensive areas outside the river levees.

Cottonwood does not renew itself on cut-over land unless special care is taken in logging. A direct effort must be made therefore to secure restocking on the ground after cutting, either naturally or by

planting. Clear cutting and eradication of undergrowth and useless trees is necessary in any case. To insure natural reproduction seed trees must be left and the soil prepared for the seed. On situations unfavorable to natural reproduction cottonwood must be planted. Planting, in fact, will probably be necessary to supplement natural reproduction over large portions of nearly every extensive bottom-land tract. Artificial reproduction is but little more costly than natural, and since under it results are much more certain, it may often be advisable to employ it exclusively.

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THE SHRINKAGE IN WEIGHT OF BEEF CATTLE IN TRANSIT.

I. Southwestern Shrinkage Work of 1910–11 . . . . . W. F. Ward.
II. Northwestern Shrinkage Work of 1911–12 . . . . . James E. Downing.
III. Northwestern and Southwestern Shrinkage Work of 1911 . . . . . W. F. Ward.
IV. Summary of the Three Years' Shrinkage Work . . . . . W. F. Ward.

I. SOUTHWESTERN SHRINKAGE WORK OF 1910–11.

By W. F. Ward,
Senior Animal Husbandman, Animal Husbandry Division.

INTRODUCTION.

The transfer of cattle from the farm or ranch to the market usually necessitates a drive to the railroad and a further journey on the cars. These drives may vary in distance from a few hundred yards to more than a hundred miles, depending upon the location of the ranch, while the railroad journey may consume any time from a few hours to several days. All cattlemen know that when their stock arrives at market they are usually lighter in weight than when they started. This loss in weight is called shrinkage. The shrinkage in weight of cattle in transit to market is the difference between the weight of the animals at the point of origin and the weight of the animals on arrival at destination. The net shrinkage is the difference in the weight at the point of origin and the weight of the animals when sold at the market.

In shipping all animals there will be some loss in weight during the journey due to excretions from the alimentary canal, from the urinary organs, and from moisture given off by the lungs in breathing. A portion of this loss may be regained at the market by the food and water taken into the system. The consumption of this food and water at the market is termed the "fill." The loss in weight which occurs while the cattle are in the cars between the point of origin and the destination is termed "shrinkage en route" or "shrinkage before fill," and the loss in weight after the animal has had feed, water, and rest is termed the "shrinkage after fill" or the "net shrinkage," or simply as the shrinkage of the animal. In all parts of

this bulletin where shrinkage is mentioned it should be understood that it is the net shrinkage which is referred to. This net shrinkage is the amount of weight lost to the shipper of the cattle, and for this reason is the shrinkage of most interest to the cattleman.

All cattlemen, shippers, and carriers of live stock are cognizant of the fact that, as a rule, there will be some loss in weight of the animals due to shipping, and if the shipping conditions are about the average, the shrinkage should be about the average or normal, and that this normal loss should be borne by the shipper. However, if the service of the carrier is poor because of accidents, delays, rough handling, or willful carelessness, it is natural to suppose that the shrinkage of the animals would be greater, and that this difference between the normal and the excessive loss in weight should be paid for by the carrier and not lost by the shipper.

Each year there are thousands of dollars involved in legal entanglements between shippers and common carriers because of this excessive shrinkage. In the Southwest the usual method of settling these claims is rather crude. It is simply a matter of opinion of those who are supposed to know something from experience about shipping cattle. These opinions are at times very conflicting. In a case in point one witness stated that cattle shipped from a certain point would shrink 90 pounds a head, while a witness on the other side was of opinion that the cattle would not shrink over 30 pounds. There are no scales in any portion of the range country of the Southwest, and all estimates of the weights and shrinkages of the animals were guesses—good ones sometimes, no doubt, but frequently very poor.

This method is an unsatisfactory way of settling claims. A knowledge of the normal shrinkage of animals moving to market will enable the shipper or cattleman to get a more definite idea of the value of his cattle at home from the market reports. If he knows approximately what the freight and other expenses on his cattle will be and also knows about what to expect from shrinkage, he can figure fairly accurately what they will bring on the market, and will be in a position to save many dollars by knowing what to ask local buyers for them. Of course, there is always the possibility of a variation in the shrinkage, a change of market, etc., which entails a little risk in shipping, and it is this risk which enables local buyers or speculators to secure cattle.

OBJECT OF THE INVESTIGATION.

The objects of the work may be briefly stated as follows:

1. To secure weights of enough cattle of each class in order that comparisons could be made of the shrinkage of one class of cattle with another for a given period of time.

2. To determine, if possible, at what period of the journey the greatest shrinkage occurred.

3. To study what effects the different methods of handling the cattle previous to loading them had upon the shrinkage in transit.

4. To note the effect of the weather at time of shipping upon the shrinkage in transit and the fill taken at market.

5. To determine the relative benefit, if any, of a good, quick run to market as compared to a slow, rough trip with careless handling of the train.

6. To see whether or not feeding and watering the cattle a short time before loading them was beneficial.

7. To note the difference in shipping cattle long distances in "feed and water" cars without unloading them, as against the method of unloading in transit to feed, water, and allow the stock to rest.

8. To study the shrinkage of cattle that have been finished for the market upon various feedstuffs.

9. To note what influence the season will exert upon the shrinkage.

10. To obtain reliable data that may be used as a basis upon which the cattleman can calculate the approximate shrinkage in weight of his cattle in shipping.

PLAN OF THE WORK.

This investigation was begun in August, 1910, and was planned to extend into the important parts of the range and feeding sections of the country and to incorporate results for the different classes of cattle when shipped under various conditions. To carry out the investigation the cooperation of both the railroads and the cattlemen had to be obtained. The cooperation of the railroads was necessary, as there were no stock scales on the ranches of the Southwest, so the cattle had to be weighed on the railroad track scales at the point of origin. The cars had to be weighed while empty and again after loading, the difference in the two weights being, of course, the weight of the cattle.

Each car was "cut loose" at each end from the other cars, so that the "pull" on the coupling would not affect the weight of the car. This required quite a little work from the crews of the switch engines, but the help was always courteously given by the railroads without charge. The shipper was asked to sign a printed form giving his consent to have the cattle weighed, so that the railroads could not be held responsible for the little delay caused by weighing the stock. The work was done very fast, requiring about one minute per car, and very little time was lost.

The weights of the animals were taken at the point of loading, on arrival at their destination, and again after having rest, feed, and

water. The last weight was the weight secured when the animals were sold.

The cooperation of the bureau officials at the market was secured, so that the weighing of the cattle on arrival could be done officially when it was impossible for the field man to follow the shipment. This was desired, as such weighing would be more accurate than if left to the railroad or stockyards employees, because the common practice among the railroad men is to record 100 pounds as the smallest break in the scales. For instance, if a loaded car weighed 54,340 pounds, it was written 54,300; if it weighed 54,360, it was made to read 54,400 pounds. With the help of the bureau officials at the markets the investigator was able to stay in the field and secure weights on many more shipments of cattle, and with far less expense, than if he had followed each shipment of cattle to their destination.

A record of the method of handling the cattle for several days previous to shipping was kept, taking into consideration the number of miles they were driven to the loading point, how often they were grazed or watered en route, the class of cattle, their condition, and whether they were fed or watered just before loading. Any other items of importance were also noted.

When cattle were on the cars so long that they had to be unloaded for feed and water their weights were secured, when it was possible, before they received feed and water, and again afterwards, and a careful record was kept of this, as well as of the amount and character of food consumed. Thus direct comparison could be made of the shrinkage for the first portion with that of the second portion of the journey, and the fill taken at the unloading station could be compared with that taken at the market.

The investigation was to cover the Southwest the first year. The work was started with the range cattle of Texas in August, 1910, and continued until January 1, 1911, when the shipping of these cattle ceased. Temporary headquarters were then transferred to Oklahoma City, Okla., which was conveniently situated with regard to other places where cattle were being fed, and work was started with cattle fed on cottonseed hulls, cottonseed meal, and corn chop and was continued until the last of February.

ACCURACY OF TRACK SCALES.

At different times during the progress of the work a check was made between the railroad track scales and the platform scales of the Fort Worth Stock Yards to test the accuracy of the track scales. On arrival at Fort Worth the cars of loaded stock were weighed, one at a time, on the track scales, and as soon as they were unloaded

the empty cars were weighed, the difference in the two weights being the weight of the stock. Each carload of cattle was then driven over the platform scales and weighed by the regular weighmaster of the Southwestern Weighers' Association. The results of this check weighing are tabulated here:

Comparison of weight of cattle on railroad track scales and on platform scales at Fort Worth, Tex.

Kind of stock.	Number of head.	Railroad track scale weight.	Platform scale weight.
		Pounds.	*Pounds.*
Calves	65	12,050	12,050
Do	65	12,650	12,850
Do	64	12,600	12,600
Do	138	38,150	38,180
Total calves	332	75,450	75,680
Cows	29	21,250	21,120
Do	35	20,150	20,190
Total cows	64	41,400	41,310

An average of the weights of all the calves shows that they were 0.7 of a pound heavier when weighed on the platform scales than they were on the track scales. The cows averaged 1.4 pounds lighter on the platform scales than they did on the track scales. When account is taken of all the animals weighed, it is seen that there was a difference of only 140 pounds on 396 head of cattle. These weights signify the accurateness of the track scales when cars are carefully weighed "cut loose" at each end and standing still upon the scales. Track scales used at various points for weighing cattle were officially tested at appointed intervals, or whenever there was reason to believe they needed it. In all cases they were found to be very accurate when proper precautions were taken about weighing.

SHRINKAGE IN WEIGHT NOT THE SAME ON ALL CLASSES OF CATTLE

Cattle for the market are divided into two general groups, range or grass cattle and fed cattle. Each of these groups is subdivided into the following classes: Calves, cows, steers, bulls, and mixed cattle.

Range cattle are as a rule restless when penned for shipping and continue so throughout the journey and while in the stockyards. Being used to the open country and not accustomed to man on foot, these cattle are frequently so nervous that they will eat and drink very little if they arrive at the stockyards but a short time before the market opens or while many people are walking about. It frequently happens, however, that when they are unloaded in the dark before people begin stirring in the yards, they will take a good fill.

Different methods are used in the stockyards to get these cattle to fill. If they arrive in the afternoon they may be given a little water and all the hay they can eat at night, and then all the water they will drink just before the market opens. This gives them weight, but does not do away with the drawn appearance so characteristic of this class of stock. As a rule they are fed only hay, as they are unaccustomed to grain and would not eat it.

Cattle which have been fed or finished for the market usually present quite a contrast to the range stock. Docile, accustomed to man and expecting feed from him, these cattle do not show the restlessness of the range stock, and when fed, if weather conditions are favorable, take a nice fill and lie down or stand about in contentment. The shrinkage on fed cattle which have had a very long journey may be rather heavy, because if they are very empty they can not and will not completely fill in a few hours' time. To do this would require at least two days. They will not take enough feed at once to put them back to their weight before shipping.

Cattle that are unloaded but a few hours before the market opens will usually take a good fill, but some look drawn, hard, or haggard even after filling if they have not had time to rest. It must be remembered that a big fill is not always most desirable. Cattle arriving at the market in the afternoon or night may fill, lie down, and not fill as heavily the next morning as cattle arriving about daylight, but they will have rested and do not look stale as might the latter, which took a big fill but got no rest. Rest alone will smooth out the drawn appearance and hard lines caused by travel. Then, too, the cattle which rested overnight and apparently had no large fill, will most likely sell for more than sufficient to offset the difference in weight. The buyer is always on the alert for good cattle with a normal or poor fill and will pay correspondingly higher prices for them than he will for the ones with an abnormal fill, because the poorly filled animals will dress out at a higher percentage.

The shrinkage on the various classes of cattle is not the same even when shipped under identically the same conditions. The difference may not at all times be great, but there is sufficient variation in the shrinkage to justify a close study of each.

It is a recognized fact among cattlemen that, when all other factors are equal, as a rule bulls shrink more than any other class of animals, although cows often come a close second, as they generally shrink more than either heifers or steers. There is usually little difference between the shrinkage on steers and heifers of the same size. The shrinkage on calves is usually small, but when compared to their live weight it runs about the same as with grown animals.

FACTORS AFFECTING SHRINKAGE.

There are many factors, any one of which may affect the loss in weight of cattle during transit. This alone makes the task of comparing the shrinkage of different shipments of cattle a tedious and at the same time difficult problem, as the chance of error is great. One shipment of cattle may show a shrinkage of 20 pounds per head, and a similar bunch of cattle shipped under seemingly the same conditions may show a shrinkage of 40 pounds. While variations are usually not quite so radical as this, it only emphasizes the point that to get an average of the shrinkage of various classes large numbers of animals must be used. The greater the number of cattle used the smaller will be the chance of error.

EFFECT OF THE SEASON.

One of the general factors that affect the shrinkage of cattle in shipping is the character of the season and the effect it has had upon pasture grasses, water supply, etc. During a very dry year, when pasture grasses are short and when the water supply has diminished until it is a long distance between water holes, the animals usually arrive at the loading point practically empty, or with far less than a normal fill. This is especially true if the cattle have been driven a long distance, say from 50 to 75 miles, for they will have had little time to graze and will have secured little feed in the four or five hours' time each day while held along the trail. In consequence of these conditions, the cattle will have shrunk very materially in weight during the drive to the loading pens, and will weigh up light there. Many times, too, the last watering place may be several miles from the loading pens, and as many cattlemen in the Southwest prefer loading their stock without having any water in the pens the cattle weigh up light, and the shrinkage in transit is small. If a good fill is taken at market, the small shrinkage in transit may be completely overcome. Such conditions were experienced throughout Texas in 1910, and the data shown for that year must be considered in the light of these conditions. During a normal year or one with plenty of rain, when grass is abundant and water plentiful, the cattle may arrive at the pens full, or with a normal fill, and absolutely different results in shrinkage will occur. The season is therefore one of the important factors worthy of consideration.

LENGTH AND CHARACTER OF TRAIL TO LOADING POINT.

The distance driven from the farm or the ranch and the methods of driving or caring for the cattle while on the trail may also materially affect the shrinkage. If the cattle were driven some distance

without feed and water and then loaded without being watered, as is quite often done in Texas, the shrinkage in transit will naturally be smaller than on cattle that had all the feed and water they wanted before being loaded. An instance of this kind is found with two shipments of cattle shipped under practically the same conditions after being loaded, but handled differently before loading. In one shipment, from Colorado, Tex., 123 cows were driven 8 miles and penned overnight in a dry lot and loaded next morning without feed or water. They shrank 33 pounds per head while on the cars before taking the fill at market. Another shipment, from Big Springs, Tex., of 90 cows that had been on trail two days with little to eat broke out of the pens at night and grazed and had water until 10 o'clock next morning, when they were rounded up and shipped. They were very full when loaded, and consequently shrank 104 pounds while in transit.

OTHER FACTORS.

As previously mentioned, the class of the cattle is another factor in the shrinkage, as steers do not usually shrink as much as cows of similar weight. The size of the cattle and the degree of fatness also cause variation. Steers weighing 1,000 pounds will shrink more than steers weighing 800 pounds, all other conditions being equal. On the other hand the well-finished or fat animals do not shrink as much as half-fat ones.

The length of time cattle are on the cars also causes variation in shrinkage. Naturally the longer they are in transit the greater will be the shrinkage, but if cattle are in transit over 36 hours the rate of shrinkage is not so great per hundred miles the latter part of the journey as during the first part. The largest shrinkage usually takes place in the first 24 or 36 hours.

The bedding in the cars may affect the shrinkage of the animals somewhat. It is well known that in cars which are well bedded with sand or similar material the cattle stand up much better and do not manifest the restlessness exhibited by animals in a car with no bedding. There is not the slipping, falling, and general uneasiness that occurs when the train is stopping, starting, or catching up slack. A poorly bedded car may do the cattle much injury by making them so tired they will want to lie down immediately upon arrival at market instead of taking a fill. Aside from this there is always the danger of losing an animal which falls in the car by being trampled. It is sometimes a difficult or impossible task for the animal to regain its feet without assistance. This is especially true if it is thin or weak.

Weather conditions affect the shrinkage of cattle perhaps more than any other factor. Where the cattle have access to feed and

water before loading, a severe change of the weather may prevent them from taking any water at all, and they may weigh up light at the point of origin, which will have a tendency to produce a smaller shrinkage than if filled under normal conditions. Then, too, a severe change of weather at the market may likewise prevent the animals from taking a fill.

THE FILL AT MARKET.

The fill taken at market depends largely upon the weather. Cattle arriving at market where everything is coated with snow and ice, or during a blizzard, or when a "norther" is blowing, will usually drink very little water and may eat little feed. They weigh up light and the shrinkage is great. Cold, rainy, windy weather prevents a good fill from being taken. Close, warm, muggy weather is also detrimental to a good fill for fat animals, as they have no appetite and will eat and drink little. If cattle have four hours or more for rest, feed, and water, and the weather is mild, with the sun shining, a good fill is practically assured. Cattle that have had a very long, hard journey have a tendency to lie down soon after reaching the pens, instead of taking a fill. In a case of this kind, if they have several hours' rest, they may then take a good fill. The fill can be increased by giving the animals hay only on arrival and turning them to the water an hour or two before the market opens.

TREATMENT OF CATTLE AT MARKET.

The treatment cattle receive on arrival at the market depends upon the hour of arrival, the class of cattle, and the journey they have had. If they arrive in the afternoon or early night, they may be given a little water and an abundance of hay. Early the next morning water may be turned on and kept before them all day. If the cattle are from the range, they will receive only hay and water. If they are from feed lots, the shipper may have them fed some crushed corn, or other feed early on the morning of sale day.

Cattle arriving just before the market opens or during the morning of the sale day will be turned to feed and water immediately. These animals, unless very weary, usually take a medium fill and are likely to be sold before they lose much of it. The care of the cattle after arrival is in the hands of the commission men, and they can usually be depended upon to see that the animals have every opportunity to take a good fill. It is not always desirable, however, for cattle to have an excessive fill at market, as the buyers are always on the lookout for such animals and will bid correspondingly lower on them. The increase in weight is seldom great enough to overcome the decrease in value of the animals because of their

abnormal fill. The skill of the feeder in such cases is shown by getting the increased weight from fill without giving the animals the appearance of being "stuffed."

DETAILS OF THE WORK.

There are many factors which affect the shrinkage in weight of cattle in transit and the fill at market. To obtain good average results it is necessary that a considerable number of shipments as well as a large collection of animals should be used. These features were carried out with respect to the range cattle, but the results obtained, as shown in the tables which follow, were ascertained under various conditions on a dry or droughty year and should be considered as such. A variation from the results shown here is to be expected in a normal year or in a year with an excessive amount of rainfall. The pastures of Texas from which the shipments were obtained had been abnormally dry. The data presented, therefore, must be considered as having been produced under conditions more favorable to a light shrinkage while in transit than might otherwise have been obtained under normal conditions.

RANGE CALVES IN TRANSIT LESS THAN 36 HOURS.

The shipments shown in Table 1 were made up entirely of Texas range calves that were shipped to the Fort Worth market and were in transit less than 36 hours. The time in transit as shown in the table is the elapsed time between the weighing at the point of origin and at market. It will be observed that the average length of time in transit was 21 hours, and the grand average fill at market was 9 pounds, while the grand average net shrinkage was really a gain in weight of 3 pounds. The total number of head was 859.

Attention is called to the performance of two shipments included in this table. One from Stanton, Tex., composed of 206 head had been on the road to the loading pens for three days and had been driven 16 hours a day. They looked absolutely empty and jaded when they were loaded and weighed at Stanton. The racks of the cars were filled with hay, and the calves weighed on the average 1 pound heavier when they arrived at Fort Worth than when they started. They took a 13-pound fill there, giving them a net gain in weight of 14 pounds per head. The other shipment was of 64 head from Big Spring, Tex. They were driven but 5 miles and looked well when loaded. They shrank 10 pounds each in transit and continued losing weight until they were sold. They would not take a fill at market, and were 3 pounds lighter when they were sold than when they arrived. Their net shrinkage, therefore, was 13 pounds per head. These two shipments were the extremes of the class, and the variation was not great for the other shipments.

The shipment of 154 calves from Baird, Tex., was in transit but 14 hours, having a much shorter haul to market than the average. During the journey the calves shrank 9 pounds each, but at the market they took a fill of 9 pounds each, which caused the weights at the shipping point and at market to be the same.

The results obtained from a shipment of 47 yearlings from Big Spring in transit 23 hours no doubt reflects somewhat the influence of conditions that existed at the time the investigation was being conducted. The record kept of this shipment, which is not included in the table, shows the animals to have lost 25 pounds each in transit, but upon arrival at market to have filled 53 pounds. This was a net gain of 28 pounds. These yearlings had been on the road to the pens for two days. They had a little hay, but no water, before they were loaded, which offers some explanation for their unusual performance at market.

TABLE 1.—*Texas range calves in transit less than 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	
206	Stanton, Tex	18	119	120	133	13	[1]+1	[1]+14	Driven 16 hours a day for 3 days. Were empty.
73	Big Spring, Tex	20	181	169	177	8	12	4	Driven 15 miles. Had water before loading.
75	do	20	150	146	152	6	4	[1]+2	Driven 18 miles. Had water before loading, medium fill.
62	do	20	235	218	227	9	17	8	Driven 18 miles. Had water before loading.
160	do	25	152	146	154	8	6	[1]+2	Driven 7 miles. Fair condition.
65	Colorado, Tex	22	209	201	210	9	8	[1]+1	Driven 4 miles. Fair condition.
64	Big Spring, Tex	26	182	172	169	[2]—3	10	13	Driven 5 miles. Would not fill at market.
154	Baird, Tex	14	194	185	194	9	9	0	Driven 5 miles. Water in pens.
	Grand average.	21	166	160	169	9	6	[1]+3	

[1] Gain in weight instead of a shrinkage. [2] Loss in weight instead of gain by fill.

RANGE COWS IN TRANSIT LESS THAN 36 HOURS.

All of the shipments contained in Table 2 were composed of Texas range cows that had been in transit less than 36 hours. The average length of time as disclosed by the grand average in the table was 21½ hours. The total number of head was 509. There is a rather wide variation in the individual shrinkage and fill, although the averages do not show it to any appreciable extent.

It will be observed that there is a sharp division in the net shrinkage results, one-half of the shipments experiencing gains after the fill at market, while the other half approach somewhat nearer a normal shrinkage.

Three of the shipments show a rather unusual performance: The shipment of 92 head gained 5 pounds each at market; the shipment of 28 head experienced a fill at market equal to the shrinkage in transit; and the shipment of 90 head filled 88 pounds each at market which cut down the rather heavy shrinkage of 105 pounds to 17 pounds net.

The shipment in the table showing the least fill is that of 123 head which filled only 5 pounds each. The records show these cattle to have been sold soon after they were unloaded at market, which did not enable them to eat or drink much, and explains why the fill at market was so light.

Of particular interest is the performance of 90 head that experienced a gross shrinkage of 105 pounds each. The history of this shipment, as disclosed by the record, shows the cows to have been driven a considerable distance to the loading station and there confined without having been given any water. They broke down the fence that night, and scattered several miles over the range. They had plenty of grass and water until rounded up the next morning at ten o'clock. The fill was so great that the shrinkage in transit was naturally heavy, but, as shown in the table, the fill at market was sufficient to reduce the net shrinkage to 17 pounds each.

The average shrinkage in transit of the 509 head of cows was 56 pounds, of which 42 were regained by fill, leaving a net shrinkage of 14 pounds per head. All the shipments were sent to the Fort Worth market.

TABLE 2.—*Texas range cows in transit less than 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	
30	Big Spring, Tex...	20	817	774	829	55	43	[1]+12	Driven 15 miles. Had no water for 24 hours before loading.
30	.....do.....	20	706	672	714	42	34	[1]+ 8	Driven 1 mile.
30	.....do.....	20	711	646	671	25	65	40	Driven 18 miles. Had water in pens.
92	.....do.....	25	646	608	651	43	38	[1]+ 5	Driven 7 miles. Cows poor.
28	.....do.....	22	811	775	811	36	36	0	Driven 4 miles. In medium flesh.
86	.....do.....	24	787	716	763	47	71	24	Driven 30 miles. Fed hay night before shipping.
123	.....do.....	18	724	690	695	5	33	28	Driven 8 miles without water. Sold soon after arrival at market.
90	.....do.....	22	829	724	812	88	105	17	Driven 2 days. In good flesh.
	Grand average.	21½	749	693	735	42	56	14	

[1] Gain in weight instead of a shrinkage.

MIXED RANGE CATTLE IN TRANSIT LESS THAN 36 HOURS.

The shipments of Table 3 were in transit for an average of 22 hours. The average weight of the 791 head was 589 pounds, being small because of the admixture of calves and yearlings with these cattle. Further evidence of the abnormal conditions that prevailed when the shipments were made is shown by the results in this table. The first shipment of 29 cattle from Colorado, Tex., had a good fill when loaded and shrank 50 pounds per head in transit, and when put on feed at market would not fill, taking on but 1 pound per head before being sold. The result was they showed a large loss in weight. The same was true of the 35 head from Big Spring, except these continued to shrink after reaching market, weighing 6 pounds lighter when sold than on arrival.

The reverse, however, is true of four of the shipments, which took a fill at market greater than the shrinkage in transit, leaving the cattle heavier when sold than when loaded at the point of origin. This was due to a certain extent to bad treatment in handling the cattle previous to loading. The shipment of 169 cattle, for instance, had been on the trail for 5 days previous to loading, with very little to eat or drink. Another consignment had no water for 30 hours before being loaded and, of course, weighed up very light. The consignment of 141 head were thin cows that had been trailed 2 days with very little grass or water. When conditions of treatment are such as just named, it is only to be expected that cattle will be very empty and weigh up light at the loading pens, and if they get a chance to fill well at market, the fill may overcome the small shrinkage experienced in shipping.

The grand average presents the fact that the cattle shrank 34 pounds in transit, and subsequently filled 31 pounds at the market, leaving a net shrinkage of but 3 pounds per head. The results reported in Table 2 show that the shrinkage was 11 pounds greater per head on cows weighing 750 pounds than on mixed cattle, which were almost 200 pounds smaller.

In addition to the cattle recorded in the table, we have a record of 34 head, loaded at Colorado, Tex., which were 25 hours in transit and weighed 675 pounds per head on loading and 671 pounds when sold at market, thus showing a net shrinkage of 4 pounds. These cattle had no water for 15 hours before loading, but as the record of shrinkage and fill at market were not secured, they are omitted from the table.

TABLE 3.—*Mixed range cattle in transit less than 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	
29	Colorado, Tex.	21	865	814	815	1	51	50	Good fill at Colorado; would not fill at market.
35	Big Spring, Tex.	27	561	534	528	[1] −6	27	33	Did not fill any at market.
169	do	23	576	551	582	31	25	[2] +6	On road 5 days; empty when loaded.
71	Colorado, Tex.	18	575	537	577	40	38	[2] +2	Had no water for 30 hours before loading.
141	Big Spring, Tex.	22	561	540	573	33	21	[2] +12	Cattle poor; on road 2 days.
159	do	21	589	554	588	34	35	1	Fed some hay but no water.
86	do	23	787	716	763	47	71	24	Fed and watered night before shipping.
28	do	23	811	759	815	56	52	[2] +4	Fat stuff.
73	do	20	269	250	269	19	19	0	Calves and yearlings; driven 18 miles.
	Grand average	22	589	555	586	31	34	3	

[1] This is a loss in weight after fill instead of a gain. [2] This is a gain in weight instead of a shrinkage.

RANGE CALVES IN TRANSIT OVER 36 HOURS.

Table 4 presents the weights and shrinkages on range calves during the second period of their transit to market. In no instance was the original weight secured at the loading point, as there were no scales at any of the towns, but upon arrival at their first feeding station the calves were weighed. All of these calves were unloaded for feed and water at Big Spring, Tex., where they took a fill of 10 to 16 pounds each. The run from Big Spring to the Fort Worth market required from 22 to 26 hours.

It is seen that the average shrinkage in transit ranged from 8 to 11 pounds per head, being very uniform in all of the lots. The fill taken at market ranged from 10 to 17 pounds per head, or practically the same as that taken at Big Spring. In every case the fill taken at market overcame the shrinkage in transit, so the calves weighed heavier at market than they did at the feeding station.

The grand average of the 475 calves gives a weight of 209 pounds at the feeding station, a shrinkage of 10 pounds before fill at market, and a net gain of 4 pounds each when sold. The grand average of Table 1 gave instead of a net shrinkage on calves for the first period of 21 hours a gain in weight of 3 pounds, while Table 4 shows instead of an average net shrinkage for the second portion of the journey, consisting of 24 hours, a gain of 4 pounds in weight.

TABLE 4.—*Range calves in transit over 36 hours.*

Number of head.	Point of origin.	Time in transit, first period.	Average weight at point of origin.	Average weight at feeding point before fill.	Time in transit, second period.	Average weight at feeding point after fill.	Average weight at destination.	
							Before fill.	After fill.
		Hours.	*Pounds.*	*Pounds.*	*Hours.*	*Pounds.*	*Pounds.*	*Pounds.*
65	Valentine, Tex.....	26	.....	.....	22½	207	198	214
65	.....do.....	26	.....	.....	22½	193	185	202
64	.....do.....	26	.....	.....	22½	205	197	213
201	Marfa, Tex.....	33	.....	194	26	204	194	204
80	Valentine, Tex.....	28½	.....	230	26	236	225	242
	Grand average..	28	.....	.....	24	209	199	213

Number of head.	Point of origin.	Average fill at market.	Average shrinkage.		Remarks.
			Before fill.	After fill.	
		Pounds.	*Pounds.*	*Pounds.*	
65	Valentine, Tex.....	16	9	[1] +7	High grade Herefords. On feed 12 hours at Big Spring, Tex.
65	.....do.....	17	8	[1] +9	Do.
64	.....do.....	16	8	[1] +8	Do.
201	Marfa, Tex.....	10	10	0	Fat calves. Filled 10 pounds at Big Spring.
80	Valentine, Tex.....	17	11	[1] +6	Fat calves. Driven 8 miles.
	Grand average..	14	10	[1] +4	

[1] Gain in weight instead of a shrinkage.

MIXED RANGE CATTLE IN TRANSIT OVER 36 HOURS.

The 1,310 head of range cattle of Table 5 presents the same variations that are shown in Table 3, where mixed range cattle were in transit less than 36 hours. All of these cattle had been in transit from 26 to 72 hours when they were unloaded for feed, water, and rest. Of the total number, 566 head were weighed upon arrival as well as upon leaving Big Spring, Tex., where they were fed and watered. This weighing showed the fill taken at Big Spring to average 57 pounds per head, which was an unusually large fill for so many cattle. The average fill taken at the market was 38 pounds per head. This is considered a medium or good fill on this class of cattle.

The shrinkage in transit varied from 12 pounds a head on a load of yearlings to 39 pounds per head for the 16 cars of steers from Haymond, Tex., and the 16 carloads of cows from Mexico. Unless the droughty year is considered, the shrinkage in transit on all of the cattle would seem extremely small. The shrinkage on most of them was very uniform.

The average amount of fill taken at market varied much more. This ranged from 18 pounds with the car of yearlings to 62 and 57 pounds, respectively, with two cars of cows from Alpine, Tex., one

of which shrank 35 pounds in transit, leaving a net gain of 27 pounds per head, and the other shrank 33 pounds per head, leaving a net gain of 24 pounds per head over the first weight taken. These fills were exceedingly large. The car of 51 yearlings took a fill of 35 pounds per head at the unloading point and a fill of but 18 pounds at market. The rest of the cattle took fills which are considered about normal.

A close study of the table reveals the fact that when all of the cattle are considered they made a net gain in weight of 3 pounds per head for the second period of 36 hours in transit. It will be remembered that Table 3 revealed a loss of 3 pounds per head on the same class of cattle for the first 36 hours in transit.

The weather continued good from the time all of these cattle were started to market until they were sold.

TABLE 5.—*Mixed range cattle in transit over 36 hours.*

Number of head.	Point of origin.	Time in transit, first period.	Average weight at point of origin.	Average weight at feeding point before fill.	Time in transit, second period.	Average weight at feeding point after fill.	Average weight at destination.	
							Before fill.	After fill.
		Hours.	*Pounds.*	*Pounds.*	*Hours.*	*Pounds.*	*Pounds.*	*Pounds.*
29	Alpine, Tex.	26	.....	.....	22½	763	728	790
35	....do.	26	.....	.....	22½	609	576	633
132	Haymond, Tex.	31	.....	462	22	527	495	526
383	....do.	31	.....	535	22	592	553	598
51	....do.	31	.....	277	22	312	300	318
141	Big Spring, Tex [2]	.....	.....	.....	46	561	540	573
539	San Tomas, Mex.	72	.....	.....	27	592	553	589
	Grand average.	36	.....	.....	26	575	540	578

Number of head.	Point of origin.	Average fill at market.	Average shrinkage.		Remarks.
			Before fill.	After fill.	
		Pounds.	*Pounds.*	*Pounds.*	
29	Alpine, Tex.	62	35	[1] +27	Cows. Took big fill at market.
35	....do.	57	33	[1] +24	Do.
132	Haymond, Tex.	31	32	1	Held on hay and water 3 days before shipping.
383	....do.	45	39	[1] + 6	Do.
51	....do.	18	12	[1] + 6	Yearlings. On feed 11 hours at unloading point.
141	Big Spring, Tex [1]	33	21	[1] +12	Had no feed for 10 hours before weighing at Big Spring, Tex.
539	San Tomas, Mex.	36	39	3	Mixed Mexican cattle in medium flesh.
	Grand average.	38	35	[1] + 3	

[1] Gain in weight instead of a shrinkage. [2] Shipped to Kansas City.

CATTLE IN TRANSIT SEVERAL DAYS.

Sometimes there are consignments of cattle originating in Arizona, New Mexico, western Texas, and Mexico which go to the Kansas City market. Several days are required to make this trip, which is a very hard one on the cattle. This is especially true if the

cattle originated in Mexico, where some of them may have been held without feed or water for quite a long period while the rest were being gathered for shipping. In Table 6 are shown the data from the shipping of 588 head of these cattle. The weights at the points of origin were not secured, but the weights were taken the second day of the trip when the cattle were unloaded for feed and water. To make the trip from this point to Kansas City required 105 hours, or over four days' time. The first shipment of cattle had no feed for 10 hours before the first weight was taken and they shrank but 42 pounds in transit, gaining back 35 pounds of it from fill and having a net shrinkage of but 7 pounds per head.

The other shipment was a whole train of 524 head of high-grade Hereford cattle from Blue, Ariz. They had been in transit 17½ hours from Blue to El Paso, where they were given feed and water for 30 hours, and took a nice fill. They left El Paso at 6 o'clock p. m. in a "norther," and soon ran into a snowstorm which lasted practically all the way to Kansas City. The weather was extremely cold, but despite this fact the cattle took a good fill at Kansas City, as they had been on the cars so long with very little to eat. The net shrinkage was 42 pounds per head for this long journey.

TABLE 6.—*Mixed cattle in transit several days.*

Number of head.	Point of origin.	Time in transit, first period.	Average weight at point of origin.	Average weight at feeding point before fill.	Time in transit, second period.	Average weight at feeding point after fill.	Average weight at destination.	
							Before fill.	After fill.
		Hours.	*Pounds.*	*Pounds.*	*Hours.*	*Pounds.*	*Pounds.*	*Pounds.*
64	Big Spring, Tex				104½	717	675	710
524	Blue, Ariz	17½			105	520	448	478
	Grand average				105	541	472	502

Number of head.	Point of origin.	Average fill at market.	Average shrinkage.		Remarks.
			Before fill.	After fill.	
		Pounds.	*Pounds.*	*Pounds.*	
64	Big Spring, Tex	35	42	7	Had no feed for 10 hours before loading.
524	Blue, Ariz	30	72	42	In a raging blizzard from El Paso to Kansas City.
	Grand average	31	69	38	

FED CATTLE IN TRANSIT LESS THAN 36 HOURS.

Of all cattle which are shipped to market those which are finished in the feed lot should shrink more uniformly. There are several reasons for this: (1) They have had practically the same treatment

for several months before shipping; (2) they have been on feed usually until a short time before loading, and the fill at the point of origin should be more uniform than with range cattle; (3) the cattle are generally fed near the loading pens and do not have to be driven long distances before shipping; (4) they are accustomed to man on foot and to feed-lot conditions and should, for these reasons, take a much more uniform fill at market when all other factors are the same.

For the above reasons it is also possible for the owner to control, to some extent, the shrinkage of his cattle by judicious care in feeding and watering just previous to shipping, whereas the shipper of range cattle can not always do this.

All of the cattle which were used to get the data for Table 7 were steers that had been fed for an average period of 120 days. They were all high-grade Hereford and Shorthorn steers, ranging from 2 to 4 years old, and showing quality above the average for range steers. The ration on which they were fed was cottonseed hulls and cottonseed meal for the first 75 days, with some corn chop added after that time. At the time they were shipped they were receiving about 6 pounds of cottonseed meal, 10 pounds of corn chop, and all the hulls they would consume, which was about 28 pounds each per day.

These steers were fat when shipped; most of them would have classed as "choice" and some would have ranked as "prime" on the Kansas City market. Each shipment was composed of steers which had been cut from the whole herd in such manner as to secure uniformity in size and quality. The care used in the cutting out and loading was extreme, and showed a combination of the skill of a ranchman and the judgment of a feeder. Each consignment of cattle consisted of 5 to 10 carloads, so the results secured from each shipment should be fairly conclusive for the conditions under which they were shipped.

The steers ranged from 1,155 to 1,320 pounds in weight, showing an average of 1,266 pounds. They were in transit from 22½ to 26 hours, and all had very good runs to market. The shrinkage in transit was very uniform, ranging from 61 to 76 pounds each, or a difference of only 15 pounds between the extremes. The fill taken at market was not uniform because of weather conditions. Every shipment was made during very cold weather and while snow was on the ground from 4 to 5 inches deep. For this reason none of the cattle filled well at Kansas City. The first two shipments filled practically the same, as conditions at market were the same.

When the next two shipments were made everything was frozen up or coated with ice at the market. The steers were given Missouri River water, which they would not drink, and were fed 6 pounds each of prairie hay. They were sold two hours after arrival and filled but 9 and 13 pounds, respectively. The result was that the

net shrinkage was very high on these two shipments. The last shipment did little better, as the conditions were almost the same. The shipment of heaviest steers, which should have filled the most, was the one that arrived during the height of a blizzard and filled only 9 pounds per head. Their net shrinkage was the largest, being 67 pounds per head.

The grand average for all of the 680 head shows they were in transit for 24 hours, shrank 71 pounds in transit, and filled but 14 pounds, leaving a net shrinkage of 57 pounds. This was 4.5 per cent of their live weight. None of the shipments were at the market over four hours before being sold, and one shipment was on the market only 1½ hours, which may account to a certain extent for the small fill taken and consequently the larger net shrinkage.

TABLE 7.—*Cottonseed-meal-fed cattle in transit less than 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	
125	Oklahoma City, Okla.	26	1,196	1,135	1,155	20	61	41	Had but 1½ hours to fill at market.
115	do	26	1,281	1,210	1,231	21	71	50	Cold, with 5 inches snow at market. Sold 2 hours after arrival.
220	do	21½	1,319	1,243	1,252	9	76	67	Everything frozen up at market. Steers took no fill.
220	do	22½	1,245	1,173	1,186	13	72	59	Given Missouri River water at market, which they would not drink.
	Grand average.	24	1,266	1,195	1,209	14	71	57	

FED CATTLE IN TRANSIT OVER 36 HOURS.

In Table 8 are shown the results of shipping 616 head of fed cattle which were in transit 36 hours or over. All of these cattle were shipped to the St. Louis market. Each consignment was made up of two to seven cars of steers which had been on feed from 100 to 120 days. All of them were high-grade Hereford and Shorthorn steers of good quality, and were fat. The ration consisted of cottonseed meal, cottonseed hulls, and corn chop.

The steers of the various shipments ranged from 733 to 1,059 pounds in weight, averaging 862 pounds. The weights on arrival at St. Louis could not be secured, as the commission firm to whom they were consigned positively refused to allow them to be weighed. It might be stated here that this was the only firm at any market that refused to let cattle be weighed on arrival, when written permission had been secured from the shipper.

The first four shipments enumerated in this table were all from the same feed lot in Wagoner, Okla., so the treatment of all was

the same for 100 days previous to marketing, and the conditions during shipment were the same. All were of about the same weight and quality and were in transit practically the same time. For these reasons the shrinkage would naturally be expected to be almost similar. The weather at market was without change during the first three shipments, but the fourth shipment arrived in a raging blizzard, one of the worst of the winter, and the cattle ate little and drank none. Snow was deep, everything was frozen over, and a biting wind was blowing. The results are clearly shown in the net shrinkages. For the first three shipments the shrinkage was very uniform, being 47, 52, and 49 pounds, respectively. Owing to the blizzard, the shrinkage on the fourth shipment amounted to 73 pounds per head because of the failure to fill, or an increase of 24 pounds each in shrinkage over the first three lots.

The two shipments from Oklahoma City were from the same feed lot as were all of the steers shown in Table 7. They were about the same in quality and degree of fatness but were smaller in size than the ones shown in Table 7, so were shipped to the St. Louis market instead of to Kansas City. These cattle are therefore directly comparable to those of Table 7.

The shrinkage on the two shipments to St. Louis was 54 and 61 pounds, respectively, or an average shrinkage of 57 pounds for the 46½ hours' journey. The average weight was 1,077 pounds. The average shrinkage of the 680 head shipped to Kansas City was also 57 pounds each, but they were about 200 pounds heavier, and the journey was of but 24 hours' duration. These figures clearly and conclusively show that the greater part of the shrinkage on these cattle occurred during the first 24 hours of the journey.

The grand average of all consignments in Table 8 shows the average time in transit to be 40 hours, the average weight to be 862 pounds, and the net shrinkage to be 59 pounds per steer.

TABLE 8.—*Cottonseed-meal-fed cattle in transit over 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination after fill.	Average shrinkage.	Remarks.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	
112	Wagoner, Okla.	36	842	795	47	Fed 120 days. Weather was fine.
117	do	36	813	761	52	Do.
83	do	37	849	800	49	Fed 125 days. Weather was good.
209	do	37	806	733	73	Arrived at market in a raging blizzard and would not fill.
47	Oklahoma City, Okla.	46	1,034	980	54	Had been on feed over 100 days.
48	do	46	1,120	1,059	61	Cold disagreeable weather at market. Took a light fill.
	Grand average	40	862	803	59	

SUMMARY OF SEASON'S WORK.

Table 9 is a condensed statement of all the preceding tables. In it are tabulated the shrinkage data on nearly 6,000 head of cattle. It must be remembered that the year in which this work was done was a very dry one, with little grass, which was conducive to a poor fill at origin and a small shrinkage in transit for range cattle. It caused no variation at all with the feed-lot cattle.

In the first figure column of the table is shown the number of shipments made of each class of animals, while the number of cattle in each class is shown in the second column. This number ranged from 475, which were calves in transit over 36 hours, to 1,310, which were mixed cattle from 36 to 72 hours in transit. Column 3 presents the average weight at the point of origin. Columns 4 and 5 present the gross shrinkage, or the shrinkage in transit. This gross shrinkage varies greatly with the various shipments of range cattle. The greatest variation was with cows, the shrinkage of which ranged from 33 to 105 pounds. There was very little variation in the shrinkage of the feed-lot cattle.

The fill at market was also quite variable with the range cattle but more uniform with the fed cattle. The average fill on the calves was 9 pounds on one lot and 14 on the other. The largest fill was taken by range cows and the smallest was naturally taken by the calves.

The small fill, 14 pounds per head, taken by the fed cattle at market is to be noted. The conditions at market were most unfavorable for a fill on every shipment of these cattle. All of them arrived when everything was coated with snow and ice.

With two exceptions, the weather was good when all shipments of range cattle were moving to market. Two shipments which were destined for Kansas City were caught in snowstorms and their shrinkage was heavy when compared with the other shipments.

The variations in the net shrinkages were quite wide for the different shipments. The greatest variation was found with the mixed range cattle in transit less than 36 hours, and the next greatest with the range cows. The difference was not so great with the calves, nor with the fed cattle. The variation was greater with the fed cattle which were in transit over 36 hours than with the ones in transit for a shorter period. This was because of the excessive net shrinkage, 73 pounds, on a single shipment which would not fill at market.

The average net shrinkage for all of the range cattle was small. All of the 1,334 calves actually took enough fill at market to overcome the shrinkage in transit, and they gained in weight. The same was true of the mixed range cattle in transit from 36 to 72 hours, while the range cattle in transit less than 36 hours lost 3 pounds each in weight. There was a loss of 14 pounds per head on the range cows.

One large shipment of cattle in transit 105 hours was in a snowstorm for four days, which increased the shrinkage quite a little over that shown by the other classes. At the points where these cattle were unloaded for feed and water they were given some prairie hay, but the water pipes were all frozen, so they got practically no water. At market they filled 30 pounds per head despite the weather.

The fed cattle in transit under 36 hours shrank 57 pounds per head, while those in transit over 36 hours shrank 59 pounds each. This was not a large shrinkage for this class of cattle.

TABLE 9.—*Summary table for 1910–11 work.*

Description of shipments.	Number of shipments.	Number of cattle.	Average weight at origin.	Gross shrinkage.		Fill at market.		Net shrinkage.		Ratio of shrinkage to live weight at origin.
				Range.	Average.	Range.	Average.	Range.	Average.	
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Range calves in transit less than 36 hours	8	859	166	[1] +1–17	6	[2] –3–13	9	[1] +14–13	[1] +3	[1] +1.8
Range calves in transit over 36 hours	5	475	209	9–11	10	10–17	14	+ 9– 0	[1] +4	[1] +1.9
Rangecows in transit less than 36 hours	8	509	749	33–105	56	5–88	42	[1] +12–40	14	1.9
Mixed range cattle in transit less than 36 hours	9	791	589	19–71	34	[2] –6–56	31	[1] +12–50	3	.5
Mixed range cattle in transit 36 to 72 hours.[3]	7	1,310	575	12–39	35	18–62	38	[1] +27– 3	[1] +3	[1] +.5
Mixed range cattle in transit 105 hours	2	588	541	42–72	69	30–35	31	7–42	38	7.0
Cottonseed-meal-fed steers in transit less than 36 hours	4	680	1,266	61–76	71	9–21	14	41–67	57	4.5
Cottonseed-meal-fed steers in transit over 36 hours	6	616	862	.....	.....	.....	.....	47–73	59	6.8

[1] Gain in weight instead of a shrinkage.
[2] Cattle did not fill at all but continued losing weight.
[3] Cattle were in transit 54 to 72 hours, but the figures are for the second portion of the journey, and not for the total time in transit.

CONCLUSIONS.

The following conclusions may be drawn from the season's work:

1. The shrinkage of cattle in transit is influenced very materially by the following factors:

(*a*) The character of the season. If a season has been so dry that grass is short and water holes far apart, the shrinkage may be small unless feed and water are given just before shipping.

(*b*) The distance driven to the loading pens and the care used when making the drive.

(*c*) The fill at the shipping point. If the cattle have had no grass and water for several hours before loading and weighing, they will naturally have a small shrinkage in transit. But if they

have plenty of grass and water before weighing, there will usually be a heavy shrinkage.

2. The shrinkage is not the same for all classes of cattle. It will be greater on cows than on either steers or mixed stuff, and smaller on calves than on any other class of cattle.

3. The shrinkage will usually be in direct proportion to the size of the animals, where all other factors are equal.

4. The weather exerts a primal influence on the shrinkage of cattle while in transit, and upon the fill taken at the market.

5. The greater the fill taken at market the smaller will be the shrinkage.

6. The fill at market may be influenced by the weather, the time elapsed since the cattle were last fed and watered, the time of arrival at market, and the feeds given while there.

7. A big fill of grass and water at the point of origin just previous to loading is not desired. The cattle will not stand up well, and it may cause them to scour.

8. The practice of withholding feed and water for from 10 to 25 hours before loading, in order to make the cattle take a big fill at market, is to be condemned. Very frequently the fill is not taken, and usually the shipper loses money by this procedure.

9. In a droughty year the shrinkage of the cattle largely takes place during the drive from the ranch to the loading pens. The shrinkage in transit may be small and may be completely overcome by the fill at market.

10. The variation in shrinkage of fed cattle is not as wide as that on range cattle, and the fill at market of the fed cattle is more uniform.

11. The shrinkage of cattle finished on cottonseed meal, hulls, and corn chop is greater than the shrinkage on range cattle.

12. The shrinkage of cattle is much greater during the first 36 hours in transit than during any subsequent period of the same duration.

II. NORTHWESTERN SHRINKAGE WORK OF 1911–12.

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INTRODUCTION.

This part of the investigation was started in September, 1911, and covered a large portion of the western cattle-producing districts. The work was carried out with the same facilities and under the same conditions that are offered to every shipper. No effort was made to influence results one way or the other, nor was there any attempt made to deviate from the regular order or methods peculiar to the section of the country where the animals originated. The aim of the investigation was to get at the facts with respect to the shrinkage in transit and the fill at market. The results obtained were based on shipments made in various sections of the country under varying conditions, with cattle of different breeds, fattened on several kinds of feed.

No attempt was made to gain control of the shipments or to influence or advise the owner how the stock should be treated. Permission was asked to weigh the animals at the point of origin and again on arrival at market. Care was always exercised to avoid any extra shrinkage by reason of the weighing or to divert the cattle in any way that would place them in a less favorable position as compared with other shipments not weighed. The object was to handle them in a normal manner without regard to what the outcome might be, so as to secure accurate results under the prevailing conditions.

HOW THE DATA WERE OBTAINED.

The investigation was begun in the vicinity of Sheridan, Wyo., in September, 1911. At that time the cattle from the ranges of Wyoming and Montana were being sent to market. The work of collecting the weights of shipments originating in that section of the country was continued until November, when headquarters was shifted to Alliance, Nebr. From this point the work was continued with shipments from the sandhills of western Nebraska. The shipping season practically closed in December and headquarters was again shifted to Boone, Iowa, where shipments from feed lots in different parts of the State were obtained. The last move was made in April, 1912, to Jacksonville, Ill., where the work was finished in June.

In February, 1912, trips were made to Billings, Mont., Brush and Fort Morgan, Colo., where weights were secured of shipments from these points to various markets in the Middle West of cattle fattened on sugar-beet pulp.

The greatest handicap encountered was the lack of scales at points of origin; especially was this true in the range States. There are but few platform scales in these States and the weights obtained of the range-fattened cattle of Wyoming, Montana, and Nebraska were nearly all on railroad scales. The weights of the pulp-fed, corn-fed, and silage-fed cattle were all obtained on platform scales and are what are commonly known as "hoof weights."

In taking weights of cattle on railroad scales care was exercised in getting as near the correct weight as possible. It is customary with some railroads in weighing freight to keep the cars coupled together and not take into account fractional parts of weights registering under 100 pounds. For example, if a loaded car weighed 55,540 pounds, the weight would be set down as 55,500 pounds and the odd 40 pounds disregarded. Moreover, the cars being coupled together at the time would also influence the weight, depending on whether the draft of the drawbars was up or down on the car weighed.

It was obvious that such a method would not furnish data sufficiently accurate for an investigation where every pound was a factor in the final results, nor would such weights furnish reliable figures to compare with the careful weights taken on platform scales at market. Hence it was found necessary in weighing on railroad scales to uncouple all cars weighed, so as to have both ends free. A careful balancing of the beam was observed and with the scales breaking at 10 pounds the weights thus secured were as accurate as the facilities would permit.

The method followed where shipments were weighed on railroad scales was to weigh the empty cars after they had been bedded. The cattle were then loaded and weighed in the cars. The weight of the car before it was loaded was subtracted from the weight of the loaded car and the result represented the weight of the animals at the point of origin.

A brief history of the cattle was taken from the owner and a note made of the conditions under which they had been trailed and loaded. Arrangements were made with bureau employees at the stockyards at the various markets whereby the cattle were weighed promptly on arrival before any feed or water had been given them, the owner giving his consent to have this done. The weights on arrival before the fill and the sale weights taken after the fill at market, together with the time of arrival, were sent to the writer, who entered them into the record of the shipment.

THE FILL AT MARKET.

Under the present system of marketing beef animals the amount of weight taken on after their arrival and before their sale is allowed the shipper by the purchaser. This extra weight is produced by feeding and watering soon after the cattle are released from the cars. The more the animals eat and drink after arrival and before sale the greater will be the weight taken on. Every pound of weight thus taken on has an equivalent in money, so that the fill at market is important to the shipper in that it is a distinct gain. Furthermore, every pound of fill at market reduces in like proportion the shrinkage that has taken place while the cattle were in transit. Thus, if a steer shrinks 50 pounds from point of origin to market and fills 25 pounds before it is sold there is but 25 pounds net shinkage to represent the transfer from farm to market.

There is no method of insuring a good fill at market that is practical or humane. As an old feeder and shipper once remarked, "One can never tell what a steer will do." This statement was predicated on long experience, and its truthfulness is attested by many other shippers. Some call a good fill luck, but it is not to be denied that conditions play a prominent part. If a system of handling could be perfected whereby a good fill at market could be counted on the shippers of beef cattle would have a difficult problem solved that is costing them no small amount of money and effort.

The prevailing custom at the market places in this country affords ample opportunity for cattle to eat and drink liberally. Animals may continue to fill from time of arrival until sold, and the amount they consume is not restricted by any stockyards rule or regulation. It is of interest in this connection to note the rules and regulations prevalent in two European countries.

CUSTOMS IN SOME FOREIGN COUNTRIES.

In Germany meat food animals in the stockyards at the principal markets can not be fed after 8 o'clock in the morning. This rule is in effect until the animals are sold or the market closes for the day, which is generally about 4 o'clock in the afternoon. In some sections of Germany animals in the stockyards may not be fed after 7 o'clock in the morning until the market closes. Another interesting regulation now in force in Munich and quite generally throughout Germany has to do with the quantity of feed that may be given each animal at feeding time after arrival at the stockyards.

The following is translated from the "Feeding Regulations" of the public stockyards in Munich, Germany:

1. The feeding of live stock in the stockyards must not take place between the hours of 8 a. m. and 4 p. m.

2. The feeding and watering of animals must be performed by the owner or his agent. Only feed delivered by the employees of the stockyards may be used.

3. All feed shall be apportioned at each feeding as follows:

(*a*) For 1 head of cattle, 5 kg. (11 pounds) of hay.

(*b*) For 1 sheep, ½ kg. (about 1 pound) of hay.

(*c*) For 1 hog, ½ kg. (about 1 pound) corn or barley.

(*d*) For 1 calf, ½ kg. (about 1 quart) meal mash.

4. The prices charged for the feed rations mentioned in paragraph 3 shall be fixed at the beginning of each month by the stockyards management and displayed about the stockyards.

5. For attendance and care and for bedding no fee shall be charged.

6. For feeding animals at other than the regular time an extra fee shall be charged, payable at the time in cash.

7. Feed or litter left in the pens, stalls, or yards may be utilized by the incoming occupant without charge.

In the principal live-stock markets of France regulations very similar to those of Germany prevail with respect to the time when animals may be fed and watered. These regulations apply to stock imported from adjacent or neighboring countries as well as native or home-grown animals.

THE TIME OF ARRIVAL AT MARKET.

The investigation revealed the fact that the time of arrival at market is an important factor in the fill. It was observed that cattle arriving at a late hour in the night do not take on as much weight as those arriving around 5 o'clock in the morning. This is especially true in winter. Cattle arriving in the early morning appear more eager to eat and drink, while those arriving at a late hour in the night when the weather is cold and a raw wind is blowing generally lie down before daylight arrives. Such cattle are disposed to remain in that position, if not disturbed, until the morning sun warms the atmosphere, and if the morning is cloudy or stormy they will remain lying down and, as a rule, appear indifferent to feed and water unless very hungry.

There is quite naturally a difference in the disposition of cattle from the range as compared with those from the feed lots. This difference in disposition is manifested on their arrival at the market as well as elsewhere. For example, cattle fattened on the western ranges, where they are practically unrestrained from birth to maturity and seldom see a man afoot, are not handled as easily as animals more domesticated. Their transfer from range to market is one constant strain. On arrival they are confined in strange quarters, the surroundings of which are occupied with strange cattle. If they are unloaded during the night they do not lie down unless fatigued with their journey. The result of this is that they are not disposed to fill very much unless very hungry.

On the other hand, cattle arriving after daylight, from 5 to 7 o'clock in the morning, without respect to whether they are from the range or the feed lots, were observed to fill more readily. In other

words, if cattle can be unloaded from the cars into the feeding pens at the market and fed promptly at somewhat near the hour of their usual feeding time, it has been noticed that they will take on a better fill than when unloaded at night. This, however, is subject to weather conditions on arrival. But the nearer the animals can follow their former hour of feeding the more naturally they will consume their usual quantity. As a rule, after having taken on the fill cattle will lie down and rest. If unloaded after daylight and fed promptly they will have sufficient time to eat and drink liberally and have a good rest before the market formally opens. The fill and the rest are both important to the shipper. Where this plan could be followed it was noticed that the animals presented a better physical appearance. The hollow spots produced by the fatigue of the journey were filled out and their general appearance was more smooth.

Hence, the nearer the regular feeding and watering time at home can be adhered to at the market yards, with good weather prevailing, the more satisfactory will be the fill. If the shipper is fortunate in arriving at a favorable hour with his cattle and can secure a natural fill he will have accomplished about all that can be expected under present methods of marketing.

GUARDING AGAINST SHRINKAGE.

All of the precautions to protect cattle from heavy shrinkage in transit may be made useless by some incident of the trip that is beyond control. As a matter of fact, when a shipper loads his animals aboard the cars for market it is largely a matter of chance as to how much weight they will lose during the journey. It was observed that some shippers exercised care in guarding against a heavy shrinkage, while others were indifferent, and the final results at market were not always in favor of the shipper who was careful. However, it is not intended to convey the idea that care and effort are not without their reward, but it sometimes happens that the painstaking shipper suffers loss that is not visited on the indifferent shipper. It is merely one of the fortunes of the business occasioned by the elements of chance that enter into the transferring of the animals from the farm to the market.

There are certain established methods of handling stock destined for market that are no doubt responsible for a lighter shrinkage in transit than would otherwise be the case. In this the railroads have endeavored to assist, although one feature they have undertaken has proved a failure—that is, the attempt to water cattle while they are in the cars. In justice to the companies that have

equipped their cars for this purpose, it must be admitted they have expended considerable sums in an attempt to furnish practical watering facilities, but the quantity supplied is usually insufficient unless considerable time is consumed, and a long train of stock to be liberally watered would occasion delays that could not be permitted.

Assuming that the watering of stock in transit is practically out of the question, it remains for the shipper to give his animals some water before loading them. Some shippers do not make a practice of doing this. They prefer to allow the thirst of the cattle to accumulate in anticipation of an increased fill at market. However, this custom is beset with risks that can not be controlled, such as long delays in transit, encountering heavy rains on the way followed by cold or snow, unfavorable weather at market, and arriving after the market has opened or at a late hour at night. All of these are factors that make the practice one of doubtful value, as it has been observed that in cases where these conditions obtain they tend to counteract the anticipated extra fill occasioned by the denial of water before loading. It appears to be the better plan to provide sufficient clean water and allow the cattle an opportunity to drink leisurely before loading them at the point of origin. Whether they shall be fed grain or hay before loading depends on how much and when they were last fed, the distance driven, the condition of the roads over which they traveled, and the weather.

These conditions of course do not apply to animals from the range. They apply especially to cattle that have been in feed lots. It was observed that when a shipper fed the usual quantity at the last feeding time on the farm before starting for the station, and drove leisurely so as not to warm the animals unnecessarily, that when they had cooled off in the station yards a light feed of oats, shelled corn, or hay was usually eaten without hesitation.

In agricultural districts where feed is plentiful it is the prevailing custom to fill the racks in the cars with hay, but in the range country this practice does not prevail to any extent on account of the scarcity of hay and the distance and inconvenience of getting it to the cars. In fact, on some roads it is not even permitted in the cars, because where certain kinds of soft coal are used in the engines there is too great a danger from flying sparks.

Many experienced shippers of feed-lot cattle contend that if the cattle are fed before loading the placing of hay in the racks is unnecessary. This contention is based on individual judgment and is not sustained by any array of facts. It was observed, however, that cattle do eat hay quite liberally, especially if it is a change from what they have been accustomed to in the feed lot. One shipper in Iowa usually fills the racks with sheaf oats, which he has saved for this pur-

pose. The oats were always consumed. An Illinois shipper bedded the cars deep with millet and filled the racks with choice alfalfa hay, the cattle having been fed all winter on clover and timothy hay.

It seems quite reasonable in view of the foregoing that when a change of feed is provided in the car racks it will be consumed. Moreover it has been observed that cattle are more contented and slightly less susceptible to excitement when they have been watered and fed liberally. If this be true, then it is fair to presume that when thus fortified for the journey the animals will experience the transfer from the farm to the market with the least shrinkage and arrive in the best physical condition possible under the conditions.

WEIGHING WARM AND COOL.

Throughout the feed-lots districts of the Middle West the railroads have provided platform scales at their principal stations, and it is a common practice among shippers to weigh their stock before loading in the cars for market. Many shippers keep an accurate account of the weights, and when the statement of the sale weights at market reaches them they are able at once to ascertain the amount of shrinkage experienced in the journey from point of origin to destination.

Some of the largest cattle raisers maintain platform scales on their farms, which enable them to keep strict account of the progress their animals are making during the feeding season. It was observed that animals which had been subjected to frequent weighing were more tractable and sustained less shrinkage in handling. Most of the farmers who have platform scales weigh their cattle just before starting for the railroad station or before the last feed is given. All of the weights thus taken are when the cattle are cool.

Where scales are provided it is the prevailing custom for cattle destined for market to be weighed promptly on arrival at the railroad station yards. The reason why the animals are weighed promptly on arrival is because it is more convenient for the shippers. The arrangement of the pens is such that it is easier to weigh on arrival and while the animals are warm than later on when they have cooled. It should be kept in mind that when the weights are taken on the farm previous to departure the cattle are cool, while the weights at the station are taken when the animals are warm. In this connection it is desired to call attention to the difference between weights taken when the animals are cool and when they are warm.

No extended investigation was made into the matter of how much cattle shrink in cooling. From the experience of veteran shippers it was learned that cattle weighing around 1,200 pounds would shrink

after an average trail from 15 to 20 pounds while cooling in the railroad pens. The distance traveled, the condition of the roads as to whether they were dry, muddy, or covered with snow, and the condition of the weather all have something to do with this loss of weight after arrival at the yards.

An experiment was made with one lot of yearlings, averaging slightly less than 1,000 pounds, that had been driven between 2 and 3 miles under normal conditions. Weights were taken promptly on arrival and again after 3 hours of rest in open pens without feed or water. In this instance the shrinkage while cooling amounted to 12½ pounds per head.

The fact that there is a shrinkage while cooling would appear to be an added reason for feeding and watering before loading when there is opportunity to do so. As before stated, it was observed that when feed was provided at the yards previous to loading it was generally consumed, with the result that the shrinkage was eliminated and the cattle fortified for the journey.

BREED NOT A FACTOR.

The investigation embraced all kinds of cattle common to the range and the feed lots. It included practically all of the beef breeds fattened on various feeds in different parts of the West and Middle West. Some of the animals were wild and difficult to manage; others were docile and quiet. Data were obtained on shipments ranging from 15 hours to several days in transit. Cattle acclimated to a rough environment may withstand more hardship and appear to be more rugged, but it was not ascertained that such cattle experienced less shrinkage in transit than others. True, the amount of shrinkage varied in individual shipments of the same breeds over like distances, but there were conditions experienced that accounted for the differences.

There was no particular difference noted between the cattle fattened on the ranges and those fattened on corn and hay. The shrinkage in transit and the fill at market of these two kinds, without respect to breed, was quite similar under like conditions. It was observed, however, that there was a difference in the fill at market of straight corn-fed cattle as compared with silage-fed cattle. It was also observed that the amount of shrinkage experienced by the animals fed on silage was somewhat more, as a rule, than cattle fattened on the range or on dry feed, but the increased fill at market was more than sufficient to offset the increased shrinkage of these animals, so much so that the records show a large percentage of increased net fill in favor of the silage feeding.

Inquiry was made of feeders in Iowa and Illinois as to whether salt was mixed in the silage with a view of creating an abnormal thirst that would reflect in the heavy fill at market, but all denied the use of salt, and further inquiry failed to locate a single instance where any attempt had been made to increase the natural thirst.

It was also noted that the breed was not a factor in this respect. Cattle fattened on the range or in the feed lots, and those fattened on pulp and on silage were not infrequently of the same breed and purchased from the same sources of supply. The question of the breed did not enter prominently into the transaction, and while shippers have their preferences of the breed they like best to feed, the records of the shipments do not reflect any difference in the shrinkage in transit or the fill at market that can be charged to breed.

DETAILS OF THE WORK.

MIXED RANGE CATTLE IN TRANSIT LESS THAN 36 HOURS.

The shipments in Table 10 were all from that section of the country known as the "Sand Hills," and consisted of western cattle that had been grazed and fattened in western Nebraska. There were 866 animals altogether, and all went to South Omaha. In general, the shipments were composed of cows, heifers, and steers varying in age from yearlings to 4-year-olds. Occasionally a shipment would have a few head of small calves.

The cattle were trailed distances varying from 1 to 30 miles. They were weighed while warm, or immediately on arrival at the railway pens, and then turned into a dry lot, where they remained until loaded into the cars.

With but three exceptions the shipments were made under normal weather conditions. The three exceptions mentioned were periods when there was a high wind and a temperature approaching zero. The figures obtained, however, do not indicate that the unusual weather was much of a factor in the shrinkage.

In the case of 23 head from Hyannis, Nebr., that refused to take a fill at market, an effort was made to get these animals to fill but without success, and they actually shrank about 184 pounds, or 8 pounds per head, while at market, although the weather conditions were normal and they arrived at a favorable hour in the morning.

The figures in Table 10 show considerable variation in the amount of fill obtained at market. There was but one shipment, above mentioned, that did not get a fill. The average fill for the 866 head was 28 pounds. The average shrinkage before the fill was 86 pounds and the average net shrinkage was 58 pounds.

TABLE 10.—*Mixed range cattle in transit less than 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
104	Alliance, Nebr.	30½	962	858	913	55	104	49	Four small calves in this shipment.
24	do	30½	1,166	1,037	1,107	70	129	59	Fed 2 bales of hay before loading.
75	do	36	888	813	853	40	75	35	All natives, trailed 11 miles.
33	do	25	767	699	714	15	68	53	All 3-year-old Angus.
45	do	22½	1,155	1,071	1,093	22	84	62	Three small calves in this shipment.
26	do	29	1,146	.....	1,101	.....	.....	45	Trailed 25 miles in extreme cold.
49	do	32	865	793	809	16	72	56	Trailed 20 miles; 39 old cows.
63	Hyannis, Nebr.	36	751	633	637	4	118	114	All natives, trailed 7 miles.
23	do	36	1,061	973	965	[1] 8	88	96	These cattle refused to fill at market.
41	do	36	1,202	1,128	1,137	9	74	65	Utah cattle, grazed in Sand Hills.
23	do	33	1,022	941	964	23	81	58	Trailed 30 miles.
29	do	33	837	766	775	9	71	67	All natives, trailed 18 miles.
130	do	26	763	709	717	8	54	46	All native yearlings, trailed 6 miles.
58	Whitman, Nebr.	29	899	830	844	14	69	55	On hay 1 week, trailed 13 miles.
55	do	29	967	882	895	13	85	72	Cows and steers, trailed 9 miles.
88	Lakeside, Nebr.	27	789	736	743	7	53	46	Trailed 9 miles in face of blizzard.
	Grand average.	30	909	823	851	28	86	58	

[1] Indicates loss instead of gain.

MIXED RANGE CATTLE IN TRANSIT FROM 36 TO 72 HOURS.

The shipments shown in Table 11 were all native cattle from ranges in Montana and Wyoming. The total number was 794. Many of these cattle were grazed and fattened on the Crow Indian Reservation in Montana. The shipments were composed of about one-half steers, the remainder being cows and heifers, with a few bulls and calves. None of the cattle were over 4 years of age. A few of the cars contained small calves, but there were not enough to make any appreciable difference in the performance of the animals in transit. With the exception of the small calves, all of the animals were trailed varying distances and loaded into the cars without feed or water in the railroad pens previous to loading. With but two exceptions all were unloaded, rested, fed, and watered at Alliance, Nebr.

All the shipments contained in the table except one were made under normal weather conditions and arrived at market under normal conditions. The one exception was from western Nebraska, where a

high wind and a temperature approaching zero prevailed at the time of loading.

It will be observed that the average fill at market is greater and the net shrinkage less in Table 11 than Table 10. This may be better understood when it is pointed out that the shipments in Table 11, with two exceptions, were unloaded, while the shipments in Table 10 were not unloaded from point of origin to market.

The grand averages of fill at market, total shrinkage, and net shrinkage for the average journey of 51 hours, as shown in Table 11, are 37 pounds of fill, 80 pounds total shrinkage, and 36 pounds net shrinkage, excluding the shipment of 153 head whose filled weights were not ascertained. It may be observed that the grand total shrinkage in Table 10 is 86 pounds for an average journey of 30 hours, while the grand total shrinkage in Table 11 is 6 pounds less for a period of 51 hours. Furthermore, the cattle on the longer journey took on a fill at market of 9 pounds per head more than those which reached their destination without unloading, while the net shrinkage was 22 pounds per head in favor of the longer haul.

It seems reasonable to infer from the results in Tables 10 and 11 that mixed range cattle shipped under the conditions named make a better showing at market when the journey has been long enough to necessitate a break for unloading and reloading.

TABLE 11.—*Mixed range cattle in transit from 36 to 72 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
52	Alliance, Nebr....	39	1,002	915	951	36	87	51	Cows and steers, 2-year-olds.
25	.....do.....	41	1,101	1,026	1,063	37	75	38	One small calf not included.
42	Big Horn, Mont..	46	1,120	1,063	1,094	31	57	26	Trailed 18 miles, all native steers.
100	Aberdeen, Mont..	54	966	876	932	56	90	34	Native cows, trailed 10 miles.
25	Parkman, Wyo...	54	979	933	980	47	46	+1	Four small calves not counted.
100	Little Horn, Mont.	46	1,072	977	1,020	43	95	52	Native cows and heifers, trailed 25 miles.
81	Sheridan, Wyo...	52	924	858	897	39	66	27	Loaded after fill at Sheridan.
153	.....do.....	55	767	657	.....	.....	110	.....	Filled weights not obtained.
106	Bridger, Wyo.....	58	953	896	920	24	57	33	Four head of calves included.
65	Little Horn, Mont.	47	1,193	1,134	1,166	32	59	27	Native 3 and 4 year old steers.
45	Benteen, Mont....	45	1,126	1,059	1,072	13	67	54	Southern steers, trailed 20 miles.
	Grand average.	51	978	[1] 898	992	37	80	[2] 36	

[1] Excluding the lot of 153 head whose filled weights were not ascertained, the grand average weight before fill is 955 pounds.

[2] Not including the 153 head whose fill was not ascertained.

MIXED RANGE CATTLE IN TRANSIT OVER 72 HOURS.

The shipments in Table 12 are all native cattle from ranges in Wyoming and Montana. The shipments were composed of 318 steers, 226 spayed heifers, and 151 head of mixed steers and cows, totaling 695 head. None of the steers or spayed heifers were over 4 years old. All of them had been grazed and fattened on the open range and trailed varying distances before loading. Most of them were trailed about 20 miles, and one shipment 50 miles, before loading.

Two of the shipments went to South Omaha, one being unloaded at Sheridan, Wyo., and delayed 20 hours because of a washout, and the cattle unloaded again at Alliance and Lincoln, Nebr.; the other was unloaded at Sheridan, Wyo., and Alliance, Nebr. The remaining shipments were consigned to Chicago and were unloaded at Alliance, Nebr., and Creston, Iowa.

All of the shipments were made and all arrived at market under normal weather conditions. Some of the cattle were confined in pens where the mud was deep at one or two of the unloading stations, but only one shipment encountered a hard rainstorm at any unloading point. So that, so far as weather was concerned on the long hauls, it was quite generally favorable throughout the journey. Another favorable factor was the arrival at market at a convenient hour. All but one shipment of two carloads arrived after daylight and in time for the morning market.

Comparing Table 12 with the preceding Tables 10 and 11, it will be observed that the grand averages for a haul consuming 75 hours are the same as regards shrinkage during the journey as for an average period of 51 hours and 6 pounds less than for an average period of 30 hours. The net shrinkage is greatest in the short haul and least in Table 11 (51 hours), the figures for the latter being 22 pounds less than for the haul of 30 hours.

The amount of fill at market is 1 pound less for the long haul of 75 hours as compared with the short haul of 30 hours, but the latter is 9 pounds less than the average for the haul of 51 hours.

TABLE 12.—*Mixed range cattle in transit over 72 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
44	Big Horn, Mont..	75	1,207	1,108	1,110	2	99	97	Native and southern steers.
51	Benteen, Mont....	74	1,043	958	987	29	85	56	Spayed heifers, trailed 20 miles.
75	Little Horn, Mont.	77	1,033	984	1,012	28	49	21	Do.
92	Sheridan, Wyo...	74	772	720	760	40	52	12	Mixed cattle, trailed 18 miles.
122	Aberdeen, Mont..	80½	1,083	987	1,015	28	96	68	Heifers (100) and steers (22), trailed 10 miles.
125	Little Horn, Mont.	74	1,085	1,000	1,036	36	85	49	3-year-old heifers, trailed 25 miles.
54	Cody, Wyo.....	101	1,000	910	936	26	90	64	Native cows and steers, trailed 10 miles.
132	Tyndell, Wyo....	[1] 61	1,055	968	984	16	87	71	Texas steers, trailed about 50 miles.
	Grand average.	75	1,030	950	977	27	80	53	

[1] Washout caused 20 hours' delay, which is not included in the 61 hours. During this elapsed time the cattle were in pens at Sheridan, Wyo., and fed a short ration.

MIXED CORN-FED CATTLE IN TRANSIT 26 HOURS OR LESS.

The shipments shown in Table 13 are composed in the main of native cattle raised on the farms of Iowa. The loads were made up mostly of steers, from yearlings to 3-year-olds, the other animals consisting of 8 cows, 3 heifers, and 1 bull, making a total of 278. One shipment of 49 head of 2 and 3 year old western Herefords represented the only lot not composed entirely of cattle native to the State. The shipments were trailed varying distances of from one-half to six miles.

The manner of feeding was very similar in all cases. The feeds consisted of corn, hay, and corn fodder, with some oil meal. Most of the cattle were weighed while warm soon after arriving at the station pens. The practice of bedding the cars with hay or straw and putting liberal quantities of hay in the car racks was generally observed.

With one exception none of the shipments encountered any stress of weather in reaching the loading stations or market. Two of the shipments were made at a time when the temperature was near zero, but there was no storm and the snow was not deep.

It may be noted later on that other shipments composed of the same class of animals and in some instances from the same points of origin will show a greater length of time in transit. This difference in time was caused in such cases by weather conditions which necessitated delays, the snow and intense cold making the movement of stock trains more difficult.

TABLE 13.—*Mixed corn-fed cattle in transit 26 hours or less.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
57	West Side, Iowa..	25¾	1,236	1,119	1,158	39	117	78	Trailed less than one-half mile.
57	Beaver, Iowa.....	26	957	891	930	39	66	27	Including 7 cows. Fed 5 bushels of oats before loading.
72	Boone, Iowa.....	23	1,390	1,333	1,343	10	59	49	Snow-bound, shipment unloaded twice.
22	Beaver, Iowa.....	23¾	1,058	990	1,038	48	68	20	Including 1 bull and 1 cow. Full of feed when loaded.
21	Ogden, Iowa.....	23¾	1,096	1,001	1,032	31	95	64	Including 3 heifers. Full of hay when loaded.
49	Scranton, Iowa...	23	1,373	1,306	1,310	4	67	63	No hay in car racks.
	Grand average.	24	1,218	1,142	1,167	25	76	51	

MIXED CORN-FED CATTLE IN TRANSIT 26 TO 30 HOURS.

The shipments shown in Table 14 were made in the main during severe weather conditions. There are in all 38 shipments, involving 1,210 animals. They constitute typical winter shipments when cattle are exposed to the elements. They also embrace extreme conditions in driving from farm to station, some shipments being driven during raging blizzards with the temperature down to 18 degrees below zero and the cattle traveling through deep snow that caused them to flounder about and become all but hopelessly stalled.

The weather conditions are an interesting factor in this table owing to their unusual nature. There were 9 shipments made when the temperature was at zero; 7 shipments when the weather was cold and clear; 6 shipments when the temperature registered 30 degrees below zero; 4 shipments in a typical western blizzard with the temperature from 15 to 18 degrees below zero; 8 shipments when the sun was shining and the snow thawing; and 4 shipments when it was cold and snowing steadily.

Six of the 38 shipments were western cattle, the remainder being native. Only 2 shipments were yearlings. 9 shipments were 2-year-olds; 18 shipments were 3-year-olds, and 9 shipments were of mixed ages.

The average distance trailed was 4½ miles, and none came a greater distance than 10 miles. Ten of the shipments were not fed before starting for the station, while 28 were fed their regular feed before the journey was begun. An unusual feature encountered was the condition of the roads over which the animals traveled from the

farm to the station. None of the shipments traveled over bare roads. The condition ranged from soft slushy snow to snow 3 feet deep, badly drifted, and covered with a hard frozen crust. This sort of footing coupled with a stiff, keen, cutting wind made travel slow and laborious.

But 9 of the shipments were cool at the time of weighing. The 29 that were weighed while warm indicate the prevailing custom to weigh as soon as the cattle reach the scales at the station. It is a fact quite well known that cattle shrink while cooling. Just how much this shrinkage is could not be accurately established owing to lack of facilities and limited time. However, a few instances where weights were taken before and after the cattle had cooled showed from 15 to 20 pounds shrinkage in steers weighing 1,200 pounds.

The average time the different shipments in the table were on full feed was 100 days. The feed in nearly every instance was corn, hay, and oil meal. Considerable rough feed, such as stalks and straw, was fed. The hay was generally clover or timothy. There was also some alfalfa meal fed. In only 3 shipments was there any stock feed fed.

Twenty-one of the shipments arrived at market during the night or early morning before daylight, the remaining 17 shipments reached their destination between daylight and noon.

Owing to the scarcity of scales on the farms, there was but little opportunity to secure the shrinkage of the cattle in traveling from the farm to the station. In only two instances was this shrinkage secured. One shipment of 3-year-old native steers driven 10 miles through soft snow, not fed before starting and weighed cool on the farm and warm at the station, shrank 19 pounds per head from farm to station. This lot had been on full feed for 125 days. Another lot of 3-year-old native steers that had been on full feed for 90 days, trailed 5 miles through 30 inches of snow in a zero temperature, weighed cool on the farm before starting and warm at the station, shrank 21 pounds each from the farm to the station.

The data in the table include a number of typical instances of the effect of extreme weather conditions on the shrinkage of cattle in transit to market. This is particularly noticeable in the case of the six shipments from West Side, Iowa, where the animals were driven distances varying from 3 to 7 miles through deep snow when the temperature was reported 30 degrees below zero. On some of the roads the snow was badly drifted, so much so that in one case the animals became stalled frequently and experienced much difficulty in extricating themselves. The cattle in these 6 shipments averaged 1,270 pounds per head at the shipping station, 1,169 pounds on arrival

at market, and 1,202 pounds each after the fill at market. These figures give an average fill of 33 pounds per head, a total shrinkage of 101 pounds, and a net shrinkage per head of 68 pounds. This figure, it may be noted, is 17 pounds higher than the average for all the shipments.

It is hardly probable that these same extreme conditions will be met with frequently. Taken as a whole, the shipments in the table are rather beyond the average with respect to adverse weather conditions. They are, however, useful in showing the performance of cattle under stress of weather and other extreme conditions.

TABLE 14.—*Mixed corn-fed cattle in transit 26 to 30 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
21	West Side, Iowa	26½	1,196	1,097	1,137	40	99	59	Two small calves included.
34	Dunlap, Iowa	28	1,580	1,466	1,519	53	114	61	Trailed 4 miles through deep snow.
36	do	28	1,330	1,252	1,287	35	78	43	Weighed cool before loading.
18	do	28	1,494	1,392	1,413	21	102	81	Trailed 5 miles through deep snow.
20	do	30	1,279	1,139	1,185	46	140	94	Weighed cool.
90	do	28	1,409	1,337	1,369	32	72	40	Trailed 10 miles through deep snow.
61	do	30	1,085	1,017	1,052	35	68	33	Weighed cool.
25	do	30	957	858	905	47	99	52	Fed corn, oats, and hay before loading.
18	do	30	1,293	1,207	1,273	66	86	20	All 3-year-old western steers.
17	do	30	1,484	1,410	1,453	43	74	31	Trailed 10 miles, weighed cool.
20	do	30	1,232	1,190	1,215	25	42	17	Do.
37	do	28	1,171	1,108	1,140	32	63	31	Western steers, trailed 5 miles.
38	West Side, Iowa	29½	1,272	1,170	1,199	29	102	73	Fed hay before loading.
20	do	29½	1,287	1,163	1,214	51	124	73	Fed hay after weighing.
37	do	29	1,254	1,163	1,199	36	91	55	Trailed 3 miles, deep snow, 30° below.
21	do	29	1,164	1,086	1,115	29	78	49	Trailed 5 miles, deep snow, 30° below.
19	do	29	1,332	1,215	1,240	25	117	92	Trailed 3½ miles, deep snow, 30° below.
35	do	29	1,451	1,291	1,328	37	160	123	Trailed 5 miles, deep snow, 30° below.
37	do	29	1,210	1,129	1,174	45	81	36	Trailed 7 miles, deep snow, 30° below.
37	do	29	1,214	1,123	1,152	29	91	62	Do.
20	do	26½	1,152	992	1,102	110	160	50	Trailed 5 miles, hay in car.
18	do	26½	1,375	1,254	1,294	40	121	81	Trailed 7 miles, hay in car.
36	do	26½	1,376	1,282	1,331	49	94	45	Trailed 5 miles, hay in car.
42	do	26½	1,137	1,070	1,081	11	67	56	Trailed 4 miles, sheaf oats in car.

TABLE 14.—*Mixed corn-fed cattle in transit 26 to 30 hours*—Continued.

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
42	Denison, Iowa....	29	1,208	1,137	1,163	26	71	45	Trailed 7 miles, blizzard, 18° below.
22	.....do.....	29	1,197	1,137	1,163	26	60	34	Trailed 5 miles, blizzard, 18° below.
56	.....do.....	27	810	725	749	24	85	61	One small calf included.
34	.....do.....	27	1,358	1,265	1,313	48	93	45	Trailed 6 miles, weighed cool.
20	Breda, Iowa.....	26½	1,196	1,117	1,158	41	79	38	Trailed 7 miles, hay in car.
62	Vail, Iowa.....	26½	1,069	983	1,022	39	86	47	All native 2-year-olds.
45	Ogden, Iowa.....	27	1,016	933	969	36	83	47	Deep snow, high wind, 15° below.
31	.....do.....	27	765	704	734	30	61	31	Trailed 5 miles through deep snow.
24	Grand Junction, Iowa.	27	1,173	1,101	1,138	37	72	35	Fed hay before loading.
20	.....do.....	27	1,368	1,239	1,272	33	129	96	Fed hay and oats before loading.
18	Boone, Iowa.....	27	1,224	1,178	1,215	37	46	9	One small calf included.
20	Elgin, Iowa.....	27¾	1,197	1,121	1,151	30	76	46	Trailed 5 miles over hard snow.
36	Woodbine, Iowa..	29	1,383	1,308	1,331	23	75	52	All native steers.
23	Jefferson, Iowa...	27	865	807	831	24	58	34	Full of hay and corn before loading.
	Grand average.	28	1,213	1,127	1,163	36	87	51	

MIXED CORN-FED CATTLE IN TRANSIT 30 TO 36 HOURS.

The shipments shown in Table 15 were made from the same State and in some instances from the same points of origin as those contained in Table 14. They were not, however, exposed to the extreme weather conditions, and they come more nearly under what might be considered normal winter weather conditions. There are 19 shipments in all, with a total of 529 animals.

Of the total shipments 9 were made when the weather was clear and thawing, 7 when the weather was clear and freezing, 1 when it was snowing, 1 when there was a blizzard with the temperature about 18 degrees below zero, and 1 shipment when the weather was clear and the temperature about zero. Nor did the cattle meet with the extremes in the matter of roads as those in Table 14. Thirteen of the shipments came in over roads that were soft, such as soft snow, slush, or soft mud. Only 6 shipments traveled roads that were covered with frozen snow. The greatest distance trailed was 10 miles and the shortest 2 miles, the average distance being 6 miles.

The average length of time the different lots of cattle in this table were fed was 110 days. The feeding was very similar to that of the

cattle in the previous table, corn, hay, and oilcake meal being the main feeds. Practically an equal number of shipments arrived at the market before and after daylight, 9 arriving after and 10 before.

A feature worthy of passing mention is the shrinkage of 21 head of native yearling steers that had been driven 2 miles through soft snow to the station and weighed immediately upon arrival. Three and one-half hours later they were weighed again after they had cooled and it was found they had shrunk 12½ pounds each. They averaged when weighed warm 955 pounds.

All of the animals composing Table 15 were natives except one shipment of 39 head of 3-year-old western steers. Of the 19 shipments in the table, 16 were weighed warm upon arrival at the station and 3 were cool at the time of weighing.

TABLE 15.—*Mixed corn-fed cattle in transit 30 to 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
40	Vail, Iowa	30¾	1,136	1,052	1,100	48	84	36	Fed 3 bushels of oats before loading.
35	Marcus, Iowa	36	1,032	969	1,005	36	63	27	Trailed 6 miles, hay in car.
19	Kirkman, Iowa	33	1,130	1,072	1,097	25	58	33	Trailed 5 miles over soft mud roads.
23	do	33	968	883	931	48	85	37	Do.
40	Audubon, Iowa	33	1,174	1,105	1,155	50	69	19	Trailed 10 miles, no feed before loading.
21	Kirkman, Iowa	34	1,063	1,001	1,045	44	62	18	Trailed 6 miles, no feed before loading.
60	do	34	1,296	1,213	1,258	45	83	38	All 3-year-old native steers.
22	do	34	1,031	973	998	25	58	33	Watered before loading.
29	Harlan, Iowa	34	697	636	658	23	61	38	Trailed 8 miles over soft roads.
19	Marcus, Iowa	35	1,084	1,007	1,046	39	77	38	Trailed 9 miles.
38	Halbur, Iowa	35	1,149	1,051	1,088	37	98	61	Fed oats before loading.
20	Schleswig, Iowa	34	577	530	549	19	47	28	Weighed cool.
9	Halbur, Iowa	35	1,133	1,058	1,110	52	75	23	Mixed with a car of hogs.
26	do	35	1,156	1,057	1,083	26	99	73	Trailed 3½ miles through soft snow.
21	Arion, Iowa	35	955	866	904	38	89	51	Shrunk 12½ pounds cooling at station.
40	Audubon, Iowa	35	1,392	1,264	1,319	55	128	73	All 3-year-old native steers.
23	Denison, Iowa	32½	1,111	1,024	1,060	36	87	51	Trailed 5 miles, blizzard, 18° below.
22	Logan, Iowa	36	1,307	1,185	1,219	34	122	88	Weighed full, loaded empty.
28	Marcus, Iowa	36	619	535	564	29	84	55	6 calves included.
	Grand average	34	1,082	999	1,037	38	83	45	

SILAGE-FED CATTLE IN TRANSIT LESS THAN 20 HOURS.

The shipments shown in Table 16 were made under normal conditions with one exception. This was the shipment of 21 head from Whitehall, Ill., which arrived at East St. Louis late in the afternoon. During the night a heavy rainstorm set in, and as the cattle were confined in open pens they were thoroughly drenched. The following morning the weather turned quite cool and the animals refused to drink. This resulted in the extremely small fill of 6 pounds per head and caused the net shrinkage to be considerably more than that of any other shipment recorded in the table. There were seven shipments in all, totaling 397 head.

The shipment of 107 head from Marshalltown, Iowa, shows a result which is out of the ordinary, as the final weights of the cattle were heavier than when they were placed on the cars. As shown in the table, the fill at market replaced the shrinkage in transit and 7 pounds more. All of the animals were 2-year-old western steers that had been fed ground oats the night previous to shipment, but were given no water. The following morning they were brought to the station in two lots, one lot being trailed 2 miles and the other 4 miles. These cattle had been fed 75 days on canning-factory silage, corn, hay, and cottonseed meal. Hay was put in the car racks before loading.

Particular attention is called to the grand average net shrinkage as shown in this table, since it is considerably smaller than the average in the other tables. In fact the difference is so marked that some explanation should be given. The very low average is due to the previously mentioned shipment of 107 head which gained 7 pounds at market. With this shipment excluded the average would be raised to 35 pounds.

In this connection it may be stated that four other shipments made under similar environment and covering an average length of 15½ hours in transit show a grand average net shrinkage of 49 pounds. These four shipments are not included in the table because the fill at market was not ascertained. There were 155 animals in the shipments, and while the net shrinkage averages considerably higher than that of the 397 cattle in the table, we are unable to advance any reasons for the increased shrinkage, owing to the incompleteness of the returns. However, if we combine the two averages we get a net shrinkage of 30 pounds for the entire 552 animals, and this would seem to be a fair average for silage-fed cattle in transit 16 hours.

TABLE 16.—*Silage-fed cattle in transit less than 20 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
44	Abingdon, Ill	15	1,212	1,166	1,195	29	46	17	No hay in cars.
33	do	12½	1,375	1,281	1,324	43	94	51	Not fed or watered after weighing.
40	Orleans, Ill	19	1,363	1,268	1,337	69	95	26	Native 4-year-olds, weighed cool.
21	do	19	1,110	1,036	1,095	59	74	15	Native 3-year-olds, weighed cool.
107	Marshalltown, Iowa.	19	1,070	1,024	1,077	53	46	[1] 7	Western 2-year-olds, gained 7 pounds.
21	Whitehall, Ill	5	1,408	1,335	1,341	6	73	67	Cold and rain at market.
131	Letts, Iowa	15½	1,297	1,210	1,260	50	87	37	Western 3-year old steers.
	Grand average.	16	1,232	1,161	1,209	48	71	[2] 23	

[1] Gain.

[2] The average net shrinkage raised to 30 pounds (see text).

SILAGE-FED CATTLE IN TRANSIT MORE THAN 20 HOURS.

All of the shipments shown in Table 17 were made under normal weather conditions. The final results at market are worthy of special attention. One feature of significance is the fill at market. The grand average of 60 pounds is considerably more than any of the fills recorded in the other tables, regardless of the feeding methods. There are 11 shipments in the table, with a total of 438 animals.

In connection with the unusually large fill in this table attention is called to the shipment of 50 head from Orleans, Ill., which had the maximum fill of 97 pounds. The record of this shipment shows the cattle to have been 3 and 4 year old western steers on full feed 217 days. They were fed corn and hay the night before shipping and the water turned off. The following morning they were weighed and driven 1 mile to the station, where they were kept in open pens without feed or water until shortly before noon, when they were loaded. The train left at noon and reached market at 9.15 the next morning. A liberal quantity of alfalfa hay was put in the car racks, otherwise the cattle had nothing to eat or drink for 24 hours. It will be observed that the gross shrinkage from farm to market was 105 pounds per head, but the unusual fill at market of 97 pounds reduced the net shrinkage to 8 pounds.

Of no less interest is the heavy shrinkage shown in a number of other shipments. There are four of over 100 pounds and three of over 90 pounds. The fact that the shrinkage is in most cases offset by a good fill at market very materially reduces the net shrinkage;

thus one shipment has but 7 pounds, one 8 pounds, and three others are under 30 pounds.

The chief point of value to be gained in this table is found in the fill at market. As compared with other methods of feeding, silage-fattened cattle as a rule are good "drinkers" at market, and usually take on a good fill. This feature is responsible for the very light net shrinkage shown in the grand averages.

It may be of interest to compare the net shrinkage in this table with that of four other shipments of silage-fed cattle which are not included because of incomplete data. These four shipments, all from Iowa, were made under normal weather conditions and have an average net shrinkage of 45 pounds for an average journey of 27 hours. If the 53 cattle comprised in these shipments are averaged with those in the table, the net shrinkage for all would approximate 34 pounds. This figure would no doubt better represent the average net shrinkage in silage-fed cattle in transit 26 hours than the slightly lower figure in the table.

TABLE 17.—*Silage-fed cattle in transit more than 20 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination.		Average fill at market.	Average shrinkage.		Remarks.
				Before fill.	After fill.		Before fill.	After fill.	
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
53	Corwith, Iowa	27	1,167	1,083	1,140	57	84	27	Not trailed, weighed cool.
59	Luverne, Iowa	28	1,196	1,103	1,167	64	93	29	Trailed 7 miles through hard rain.
18	Dallas Center, Iowa.	34	1,353	1,218	1,278	60	135	75	Weighed cool, no hay in car.
39	do	34	1,198	1,077	1,127	50	121	71	Weighed full and cool at station.
71	Clayton, Ill.	23	653	597	646	49	56	7	Weighed cool, no hay in car.
39	Elgin, Iowa	23	1,227	1,128	1,181	53	99	46	Not trailed, weighed cool.
43	do	23	1,025	930	987	57	95	38	Weighed full at station.
28	Harper, Iowa	23	1,183	1,109	1,158	49	74	25	Native 2-year-old steers.
21	Keota, Iowa	22	1,258	1,130	1,215	85	128	43	Trailed 1 mile, loaded full.
17	Carthage, Ill.	20	955	875	902	27	80	53	Weighed cool and full at home.
50	Orleans, Ill.	21	1,473	1,368	1,465	97	105	8	Weighed cool, trailed 1 mile.
	Grand average.	25½	1,121	1,029	1,089	60	92	[1]32	

[1] The average net shrinkage raised to 34 pounds (see text).

BEET-PULP FED CATTLE.

The data concerning the shrinkage in transit of cattle fed principally on beet pulp are not as complete as those given in the preceding tables for the other market classes of cattle. However, through the courtesy of the Great Western Sugar Co., of Denver,

we are able to present some details, including the net shrinkage and methods of feeding, for upward of 3,600 cattle which were fed and marketed in 1911 and 1912. The great majority of these cattle were fed and shipped at several points in Colorado, the remainder being shipped from Billings, Mont. The details will be found in Table 18, which follows a brief discussion of the principal features bearing upon the shipping, shrinkage, etc., of these cattle.

TIME AND DISTANCE TO MARKET.

The distance traveled to market by the Colorado cattle was approximately as follows: To Omaha, 450 miles; St. Joseph, 520 miles; Kansas City, 580 miles; St. Louis, 825 miles; Chicago, 1,000 miles. The Montana cattle traveled slightly over 1,300 miles. The probable time consumed in the journey from Colorado to the various markets would be as follows: Omaha, 38 hours; St. Joseph, 57 hours; Kansas City, 60 hours; St. Louis, 70 hours; Chicago, 72 hours. The time in transit from Billings, Mont., to Chicago was 87 hours by the shipments that were unloaded at Glendive and Staples, and 119 hours by those unloaded at Mandan and St. Paul.

SHRINKAGE IN TRANSIT.

It will be noted that the average shrinkage in transit increased with the length of the journey, except in the case of the cattle marketed at Omaha, of which there was only a single shipment—not enough to form a reliable estimate. Thus the average shrinkage to St. Joseph, including the 1912 shipments, was 36 pounds per head; to Kansas City (1911 and 1912), 55½ pounds; to St. Louis, 68 pounds; and to Chicago (all shipments), 88½ pounds.

FILL AT MARKET.

No record was kept of the fill at market except in the case of two of the shipments from Billings, Mont. In one case 20 head filled 11 pounds each; in the other 190 head filled 26 pounds each; the average for both shipments being 24½ pounds per head.

SHRINKAGE BEFORE LOADING.

An interesting point in connection with these pulp-fed cattle is the shrinkage which occurs just previous to loading them for market. It is the custom to take the cattle off the regular ration and give them nothing but hay the day before loading, and no water for half a day. We have a record of what this shrinkage amounts to in the case of two lots, which, although the results differ widely, will give some indication of what it is.

One lot of 88 head fed at Brush, Colo., when taken off the pulp ration at 10 p. m. weighed 112,740 pounds and at 8.45 p. m. the

following day when loaded weighed 106,745 pounds, the total shrinkage being 5,995 pounds and the average shrinkage 68 pounds.

Another lot of 92 head at Fort Morgan, Colo., weighed 111,090 pounds at the end of the feeding and 108,150 pounds at loading time, the total shrinkage in this case being 2,940 pounds and the average shrinkage 32 pounds.

METHODS OF FEEDING.

A line on the feeding methods with pulp cattle may be had from the following instances of rations fed, which have been kindly furnished.

The average daily ration of 3-year-old southern steers fattened at Sterling, Colo., in 1911, average time on feed 179 days, was as follows:

	Pounds.
Beet pulp	89.1
Alfalfa hay	11.4
Molasses-alfalfa hay	4.2
Molasses	2.0
Cottonseed cake	1.8
Ground corn	2.3
Straw	.56
Sorghum	.23
Salt	.004

The average daily ration of a shipment of 88 head of 3-year-old steers, fed at Brush, Colo., and marketed in February, 1912, after being on feed 110 days, was as below:

	Pounds.
Beet pulp	90–100
Alfalfa hay	12
Molasses-alfalfa hay	6
Cottonseed cake	1½
Ground corn	3

TABLE 18.—*Beet-pulp-fed cattle in transit from 2 to 5 days.*

Date of shipment.	Shipping point.	Unloading station.	Market.	Number of cattle.	Days on feed.	Average net shrinkage.
						Lbs.
1911	Brush, Colo.	Lincoln	Omaha	56	[1]	66
1911	Sterling, Colo.	do	St. Joseph	63	146	60.3
	do	do	do	57	146	18.5
	do	do	do	124	160	[2] 5.2
	do	do	do	96	209	85.2
	do	do	do	40	226	45
	Brush, Colo.	do	do	83	[1]	31
	do	do	do	42	[1]	55
	do	do	do	111	[1]	50
	do	do	do	52	[1]	83
Average for St. Joseph, 1911.					170	50

[1] Figures not available for separate shipments, but the average number of days on feed for all the shipments from Brush, Colo., was 164.

[2] This shipment gained in weight after the fill at market. The cattle were taken off pulp 22 hours before shipping and put on dry feed. They shrank 68 pounds per head during this time.

TABLE 18.—*Beet-pulp-fed cattle in transit from 2 to 5 days*—Continued.

Date of shipment.	Shipping point.	Unloading station.	Market.	Number of cattle.	Days on feed.	Average net shrinkage.
						Lbs.
1911	Sterling, Colo.	St. Joseph	Kansas City	63	146	53.3
	do	do	do	57	146	58.1
	do	do	do	54	146½	6.7
	do	do	do	36	146½	30.4
	do	do	do	96	210	88.3
	Brush, Colo.	do	do	111	(1)	55
	do	do	do	52	(1)	82
Average for Kansas City, 1911.					165	57.5
1911	Sterling, Colo.	Lincoln and St. Joseph.	St. Louis	102	189	84.4
	Brush, Colo.	do	do	125	(1)	48
	do	do	do	111	(1)	58
	do	do	do	151	(1)	81
Average for St. Louis, 1911.					171	68
1911	Sterling, Colo.	Lincoln and Montgomery.	Chicago	103	146	14.9
	do	do	do	102	189	132
	Brush, Colo.	do	do	75	(1)	100
	do	do	do	75	(1)	71
	do	do	do	64	(1)	83
	do	do	do	64	(1)	112
Average for Chicago, 1911.					165	83.4
Jan. 20, 1912	Sterling, Colo.	Lincoln	St. Joseph	87		38
Jan. 26, 1912	do	do	do	98		17
Feb. 5, 1912	Brush, Colo.	do	do	88	110	2.6
Feb. 10, 1912	Fort Morgan, Colo.	do	do	88		[2]3.9
Do	Sterling, Colo.	do	do	88		28
Feb. 23, 1912	Fort Morgan, Colo.	do	do	92	125	16
May 13, 1912	do	do	do	68	225	65
May 18, 1912	do	do	do	84	230	30
Average for St. Joseph, 1912.						22.5
May 13, 1912	Fort Morgan, Colo.	Lincoln	Kansas City	68	225	42
Jan. 30, 1912	Billings, Mont.	Mandan and St. Paul.	Chicago	36	104	120
Do	do	do	do	275	104	82
Do	do	do	do	86	104	122
Feb. 7, 1912	do	Glendive and Staples.	do	20	164	79
Do	do	do	do	90	164	99
Do	do	do	do	190	164	85
Average for Chicago, 1912.						92

[1] Figures not available for separate shipments, but the average number of days on feed for all the shipments from Brush, Colo., was 164.

[2] This shipment gained in weight after the fill at market. The cattle were taken off pulp 22 hours before shipping and put on dry feed. They shrank 68 pounds per head during this time.

SUMMARY OF SEASON'S WORK.

The summary of all of the tables in Part II is shown in Table 19. The gross shrinkage, or the shrinkage in transit, is seen to vary greatly with all cattle regardless of which class they are in. The greatest gross shrinkage occurred with the feed-lot cattle, although the difference between them and the range cattle in this respect was very slight. The highest as well as the lowest loss of weight in

transit was experienced by the cattle fed on silage. In general it may be seen that the shrinkage in transit was very uniform for all classes of the cattle.

Contrary to the universal opinion that range cattle do not fill as well at market as finished cattle, it is to be noticed that there is little difference between the fill taken by the grass cattle and the corn-fed cattle. The range cattle, however, had the advantage in that the majority of them went to market in the early fall, while the weather was good and conditions were favorable for a good fill. This was not the case with the fed cattle, which experienced some very severe weather at market.

An important point shown in the table is the large fill taken by the cattle which were fattened on silage. They showed the greatest gross shrinkage, but the fill taken was so large that the net shrinkage on these cattle was the least of all.

The net shrinkage on all the cattle was very uniform. The figures show that as a rule the greatest shrinkage occurs during the first portion of the journey. The two exceptions to this are the range cattle in transit from 36 to 72 hours and the corn-fed cattle in transit from 30 to 36 hours.

TABLE 19.—*Summary of northwestern work of 1911–12.*

Class.	Number of shipments.	Number of cattle.	Average weight at origin.	Gross shrinkage.		Fill at market.		Net shrinkage.		Ratio of net shrinkage to live weight at origin.
				Range.	Average.	Range.	Average.	Range.	Average.	
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per ct.*
Mixed range cattle in transit less than 36 hours	16	866	909	53–129	86	−8– 70	28	35–114	58	6.38
Mixed range cattle in transit 36–72 hours	11	794	978	46–110	80	13– 56	[1] 37	+1– 54	[1] 36	3.68
Mixed range cattle in transit over 72 hours	8	695	1,030	49– 99	80	2– 40	27	12– 97	53	5.09
Mixed corn-fed cattle in transit less than 26 hours	6	278	1,218	59–117	76	4– 48	25	20– 78	51	4.19
Mixed corn-fed cattle in transit 26–30 hours	38	1,209	1,214	42–160	87	11–110	36	9–123	51	4.20
Mixed corn-fed cattle in transit 30–36 hours	19	527	1,086	50–128	84	20– 55	39	18– 88	45	4.15
Silage-fed cattle in transit less than 20 hours	7	397	1,232	46– 95	71	6– 69	48	+7– 67	[2] 23	1.87
Silage-fed cattle in transit over 20 hours	11	438	1,121	56–135	92	27– 97	60	7– 75	32	2.85
Beet-pulp fed cattle in transit from 2 to 5 days	42	3,623	.....	.....	.....	.....	.....	.....	61	.....

[1] Not including 153 head for which fill was not ascertained.

[2] This average is unusually low because of one shipment of 107 head which actually gained 7 pounds per head after the fill at market. If this shipment is left out the average net shrinkage of the remaining 290 is raised to 30 pounds.

CONCLUSIONS.

THE SHRINKAGE IN TRANSIT.

Cattle allowed to cool in the station pens at point of origin and given a moderate allowance of water and a light feed of hay before loading appear to endure the journey with less shrinkage and take

on a more natural fill at market than animals denied both water and feed before loading. If cattle are not fed or watered before loading and unusual delays are experienced they may arrive at market so tired from the jolts and long standing as to prefer lying down to eating or drinking, or so hungry and thirsty that they will eat and drink so much at market as to attract attention.

THE FILL AT MARKET.

The best that can be expected at market is a natural fill. All plans and preparations made in anticipation of a natural fill may be upset, however, by conditions encountered in transit or upon arrival. The custom that now obtains in the market of allowing cattle to eat or drink until sold provides the shipper every opportunity to have his animals in the best physical condition. There are no restrictions placed by the stockyards management as to how much or what he shall feed, or when he shall water his animals. The shipper is permitted to exercise his own judgment in the matter, so that misfortunes encountered in transit or on arrival may in a measure be overcome by exercising good management at market.

WEIGHING BEFORE LOADING.

Where opportunity will permit and scales are available it is considered advisable to weigh animals before loading. There are two very good reasons to support this suggestion.

1. The weights taken before loading provide the shipper with the means of knowing exactly what the shrinkage has been from the farm to the market. Furthermore, if he has fattened the animals the weights before loading will also supply him the information needed to determine the progress of his feeding.

2. In the event that his shipment meets with disaster in transit the before-loading weights supply an intelligent basis for the recovery of his loss, and the same applies in case his shipment has encountered prolonged delays resulting in excessive shrinkage in transit.

Many of the larger railroads traversing the cattle-producing sections, with the exception of the western range country, have platform scales in the station pens at the more important loading points on their lines. These scales are at the disposal of the shipper, and no restrictions are placed on their use in connection with the shipment of live stock. It is suggested in this connection that shippers who know in advance of the approximate time of their loading should personally ascertain if the scales are in good working condition.

III. NORTHWESTERN AND SOUTHWESTERN SHRINKAGE WORK OF 1911.

By W. F. Ward,
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INTRODUCTION.

The beef-cattle industry of the Northwest is still one of importance and contributes extensively to the supply of cattle sold on the Chicago, St. Paul, and Omaha markets. It is true that there are not so many cattle raised and shipped from that section as there were ten years ago. The invasion of the large grain farmers, the small farmers, the homesteaders or "squatters" and the sheepmen have been a series of blows which have been felt very materially by the cattle industry. There are some people, even some of the older cattlemen, who seem to see the doom to their kind and death to their industry. In a way they are right. The "old timers" must go, and with them their traditions and their methods. The ever-increasing values of some of the lands of the Dakotas, Montana, Wyoming, Colorado, and Nebraska, due to their settlement by farmers and their use for the production of grain, are naturally raising the valuation of the grazing lands, and thus raising the cost of producing beef under range conditions. The large ranges of the Northwest are being cut up into small farms wherever practicable, and draft animals are replacing the tough and blocky ponies of that section. The many men with very few cows are taking the land from the few men with many cows.

Although the number of cattle shipped from these ranges during the past year has dropped to less than half the amount of six years ago, it does not naturally follow that the decrease will continue until this section is no longer a cattle country. It always will produce a large number of cattle, since there are immense areas of this land which can be used for grazing only. Some of it is not suitable for farming, and on these tracts cattle and sheep will abound. Then, too, the farmers, although they usually raise grain only, will have to begin raising some live stock to keep up the fertility of their soil and eventually to consume part of their grain.

The same thing will probably happen here that came to pass in Illinois and Iowa. Many of the grain farmers will become stock

farmers, and although they may not raise the former range cattle, they will most likely raise better ones and will finish many of them on the farms.

In some parts of the semi-arid Northwest where irrigation is not feasible and dry farming is too uncertain, the ranchman will possibly hold sway for generations to come. Here, then, will be found the man who will continue to raise cattle, and who will be interested in any phase of cattle investigations which may accrue to his benefit. The shrinkage of his cattle in transit is an item of vital interest to him because of the great distance to market, and any information which would throw light on this subject is therefore valuable. The trade from the Pacific coast is developing to such an extent that buyers are covering all of this section. If the cattleman knew approximately what his cattle would shrink in shipping to market, and knew his freight rate and other expenses incidental to shipping, he could quickly estimate from the market quotations what his cattle were worth on the farm and would be in a position to price them intelligently to prospective buyers.

There has been less complaint about shrinkage in the Northwest than in the Southwest for several reasons: The facilities for shipping are usually better, the cattle trains make faster time, and the facilities for feeding and watering the cattle at points in transit are better. The Northern Pacific road is to be especially commended for the facilities for unloading and feeding stock at their new yards at Staples, Minn. Forty cars can be "spotted" for unloading at one time, and the cattle can be very quickly unloaded and penned with feed and water before them. The manager of the yards is advised by wire of the number of cars to be fed there, and feed and water are in the pens when the cattle arrive, so there is no delay in allowing the cattle to fill. The yards are equipped with both open and covered pens, the latter to be used in case of bad weather. The pens are away from the town, where the animals can be absolutely quiet and not disturbed until reloading time. It is to be noted that cattle unloaded at this point invariably took a good fill and had a quiet rest which enabled them to stand the remainder of the journey to St. Paul or Chicago well.

The distances the cattle have to be driven to the loading pens are usually shorter than in the Southwest, and as grass is usually abundant during the shipping season they arrive at the pens in very good condition. As a rule the cattle are larger and in better flesh and are strong enough to stand up well during the long journey.

The shrinkage investigation in the Southwest described in Part I of this bulletin brought out the fact very clearly that to get accurate results on the shrinkage of cattle large numbers must be used, because there are so many factors that may influence a single shipment or

a few shipments that the results could not be taken as a general average for future consignments. Realizing that additional data were necessary to make the investigation comprehensive and complete, the work was begun in the Northwest in September, 1911, and continued there until the end of the shipping season for range cattle. It was then taken up again in the Southwest with range cattle and continued until the movement of these cattle ceased.

LESSENING THE SHRINKAGE.

Many shippers in the Northwest realize that if cattle are handled carelessly there is apt to be a heavy shrinkage, and to a certain extent they try to avoid it. This is done by using judgment in trailing the cattle to the loading pens, grazing on the way, avoiding too long a drive without resting, and giving animals some feed and water before loading. Some shippers contend that cattle should have no feed and water for four to eight hours previous to loading. Nearly all agree that an abnormal fill just before loading has a very detrimental effect upon the animals. There is a natural tendency for all cattle to lie down after feeding, and if the cattle are abnormally full when loaded they do not stand up well in the car. In these circumstances some will lie down and get trampled. A light feed of prairie hay, about two bales to each car of stock, and some water, not all they will drink, is the most desirable feed for cattle before loading. Alfalfa is not so desirable, as it has a tendency to loosen the bowels. Sometimes hay is put in the racks of cars; and if cattle have been trailed a long distance with little to eat, the hay will be relished by them and they will not be quite so restless. If they were fed just previous to loading, however, and are to be unloaded at some good feeding station, the hay in the racks is superfluous.

Some of the railroads continue to use "feed and water" cars, so that cattle will not have to be unloaded on the way to market. These, however, are unsatisfactory, for if only enough animals are put into the car so they can lie down to rest the load will be very light and the proportionate freight on each animal will be high. On the other hand, if they are loaded as are the normal stock cars the animals get very little feed and water, and can not lie down.

LARGE SHRINKAGE NOT ALWAYS AN INDICATION OF POOR TREATMENT.

The shrinkage of animals depends to a large extent upon their treatment prior to loading at the point of origin. If they have had plenty of feed and water before being loaded they will show a rather large shrinkage, whereas a shipment which has had rough treatment and no feed or water before loading may be so empty when loaded that the fill taken at market may overcome the shrinkage in transit.

Of course, in a case of this kind the shrinkage of the animals occurred on the trail, and they were in abnormal condition when first weighed.

An illustration of the above was found in two shipments of cattle originating at Dickinson, N. Dak., on October 13, 1911. One shipment of 28 head of mixed cattle were driven very slowly for 15 miles to the loading pens. They were drifted along, grazing as they went, and arrived at the loading pens with a medium fill and looking perfectly fresh, as if they had not been driven more than a mile. The other shipment of 32 head of similar cattle was rounded up and driven 20 miles without water, and held overnight and next morning without feed or water. They were very empty when loaded and certainly looked bad, showing the kind of treatment they had received. After the fill at market they were 2 pounds heavier than when weighed at the loading pens. Both shipments were sent to South St. Paul and received similar treatment after being loaded.

The treatment of these two lots of cattle had been such as to cause the shrinkage of the second shipment to take place during the drive from the ranch to the loading pens, whereas the first arrived at the pens in normal condition and consequently shrank in transit. The first shipment showed a loss in weight of 25 pounds per head but looked well at market, while the other showed a gain of 2 pounds in weight but looked very ragged. This difference in the appearance of the two lots of cattle caused a variation in price in favor of the first shipment, which far more than offset the difference in shrinkage, to say nothing of the loss on the second shipment during the trail to the loading point.

DETAILS OF WORK IN NORTHWEST.

The shrinkage of range cattle in the Northwest will first be discussed, followed by the presentation of the work done in the Southwest.

RANGE STEERS IN TRANSIT OVER 36 HOURS.

In Table 20 are presented the results of the shipment of 730 head of range steers to the Chicago market. The first three shipments of these cattle were weighed five times, namely, at the point of origin; at the feeding station before and after having feed, water and rest; on arrival at their destination; and again after receiving their fill there. A complete record was therefore secured on these cattle from the time they were loaded near the ranch until they were sold on the market.

The first three shipments in the table were steers of about the same size and quality. They were shipped under practically the same conditions and were on the road the same length of time. They were also unloaded for feed and rest at the same pens and all were treated alike. The results obtained from shipping these three lots

of steers, each of which consisted of two to five carloads, should give a fair average for this class of cattle.

These three shipments were composed of high-grade Hereford steers, 3 and 4 years old, and were in good flesh. They were good grass-fat steers, showing quality and breeding, and were very smooth for range cattle. They were drifted from the ranch to the loading pens, being herded along the way. All were in good condition when loaded. In weight they ranged from 1,225 to 1,420 pounds each at the point of origin, and were in transit 35 hours from the loading points to Staples, Minn., where they were unloaded for feed and rest. During this stage of the journey the shrinkage for each lot varied from 70 to 96 pounds per head, the average for all being 79 pounds. While at Staples they took on an average fill of 40 pounds, leaving a net shrinkage of 39 pounds per steer for the first 35 hours in transit. The fill taken by each lot was almost exactly the same.

The run from Staples to Chicago, the second stage of the journey, required 35 hours, or the same as for the first stage. The average shrinkage for the second stage was 72 pounds, as compared with 79 pounds for the first stage. The average fill taken at Chicago was 41 pounds, leaving a net shrinkage of 31 pounds per head for the second stage. The average net shrinkage for the first stage, as stated above, was 39 pounds. The fill taken by each shipment of cattle was very uniform at Chicago as well as at Staples, and the average fill at each place was practically the same, being 41 and 40 pounds, respectively. The average time in transit for the whole journey was 70 hours, and the total average net shrinkage per head was 70 pounds.

The last two shipments in the table originated on the Standing Rock Indian Reservation at Walker, S. Dak., and were shipped to Chicago. These were all high-grade Hereford steers that had been raised in Wyoming and shipped to South Dakota for grazing. All were 3 and 4 year olds of good breeding and quality. They were shipped over the Milwaukee road in "feed and water" cars. The treatment each bunch of cattle received before shipping and during transit was the same. Several days were taken in rounding them up. They were herded on good grass (Buffalo grass) until time for shipping. They were cut out the day before shipping and herded the morning of the shipping day for five hours on grass and near water, and were then cut into car lots, penned, and loaded.

The first shipment consisted of 13 carloads, or 315 head, and the second shipment of 8 cars, or 212 head. The weather was fine at time of loading and continued so until the cattle were sold. The first shipment was delayed 20 hours because of a wreck, and the cattle were consequently held in the cars for 76 hours. The second shipment made good time, being in transit but 55 hours. Each car of cattle was given 2 bales of prairie hay and some water at Montevideo, Minn.

As these cattle were fed and watered in the cars and were not unloaded, the shrinkage for the first 36 hours could not be secured. The first shipment had a net shrinkage per head of 72 pounds, and the second shipment shrank 67 pounds per head. The average shrinkage on the two shipments for the whole journey was 70 pounds.

It is of interest to note that all the five shipments in the table were shipped under the same conditions, except that the first three were unloaded for feed and water, whereas the last two were fed and watered in the cars; and the shrinkage was exactly the same in each case. The steers in the last lot from Walker, S. Dak., were a little lighter in weight and were in transit a few hours less, which would give them a little advantage over the other lot.

Notwithstanding the fact that the shrinkage by the two methods of shipping may be the same, the cattle that are rushed through on a long journey in the feed and water cars will naturally look more jaded when they reach the market, because they do not have the same chance to rest while in transit.

The first three shipments of Table 20 lost 5.5 per cent and the last two shipments 6.3 per cent of their live weight in transit to market. The average for all the steers shows a shrinkage of 5.9 per cent of their live weight.

TABLE 20.—*Range steers in transit over 36 hours.*

Number of head.	Point of origin.	Time in transit, first period.	Average weight at point of origin.	Shrinkage, first period.		Average fill, first period.	Time in transit, second period.	Shrinkage, second period.	
				Before fill.	After fill.			Before fill.	After fill.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Hours.*	*Pounds.*	*Pounds.*
115	Forsyth, Mont.	35	1,226	70	31	39	36	75	34
46	do	35	1,307	86	47	39	35	77	36
42	Glendive, Mont.	32	1,420	96	54	42	35	55	15
315	Walker, S. Dak.	.....	1,176	Fed and watered in cars.				.....	.....
212	do	.....	1,132	do				.....	.....
	Grand average[1]	34	.....	79	39	40	.....	72	31

Number of head.	Point of origin.	Fill at market.	Total time in transit.	Total shrinkage.		Remarks.
				Before fill.	After fill.	
		Pounds.	*Hours.*	*Pounds.*	*Pounds.*	
115	Forsyth, Mont.	41	71	106	65	Drifted 18 miles in 2 days. Medium fill.
46	do	41	70	124	83	Handled same as the 115 head. These were larger and coarser steers.
42	Glendive, Mont.	40	67	109	69	Were drifted 8 miles. Fed bright hay night before and morning of shipping.
315	Walker, S. Dak.	.....	76	.....	72	Were drifted 42 miles. Grazing fine. Only medium fill.
212	do	.....	55	.....	67	Do.
	Grand average[1]	41	68	.....	70	

[1] These averages are for the first three shipments in the table, excepting total time in transit and total net shrink.

RANGE COWS IN TRANSIT OVER 36 HOURS.

The results from the shipping of three consignments of range cows from Forsyth, Mont., to Chicago are recorded in Table 21. There were 126 head of these cows, and they ranged from 942 pounds to 1,088 pounds in weight. All were high-grade Herefords.

The first two shipments were rounded up 12 days before shipping, herded for 10 days, and on the eleventh day were driven 16 miles and herded. The twelfth day they were driven 2 miles to the loading pens. They had grass, but no water, for six hours before loading. These were large cows, averaging 1,073 pounds, and were smooth, showing quality and finish. They had a medium fill when loaded and showed that they had been handled well. The shrinkage on these cattle was very uniform and in direct proportion to their weights. For the first 36 hours they shrank 41 and 43 pounds, respectively, and for the next 36 hours they shrank 26 and 29 pounds, respectively, making a total shrinkage of 67 and 72 pounds per head.

The third shipment of 51 cows was rounded up 10 days before shipping and was drifted 50 miles. These cows were not as large and not as fat as those of the other two shipments. They had grass and water until the morning of the day they were shipped and then got no more. They were loaded in the afternoon, and were rather empty. During the journey they received the same treatment as the others, being fed at Staples, but they were a little longer on the road. Their shrinkage for the first and second stages of the journey was 34 and 16 pounds, respectively, making a total of but 50 pounds per head.

The smaller shrinkage of the third shipment was primarily attributed to their poor fill at the point of origin and to their smaller size. Notice should be taken of the uniformity of fill for all shipments at both Staples and Chicago. It was practically the same at each place for each shipment.

The percentage of shrinkage to their live weights was 6.3, 6.6, and 5.3 per cent, respectively, for the three lots, with an average of 6 per cent for all. The average percentage of shrinkage for the first period of the journey (36 hours) was considerably less, namely, 3.82 per cent.

TABLE 21.—*Range cows in transit over 36 hours.*

Number of head.	Point of origin.	Time in transit, first period.	Average weight at point of origin.	Shrinkage, first period.		Average fill, first period.	Time in transit, second period.	Shrinkage, second period.	
				Before fill.	After fill.			Before fill.	After fill.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Hours.*	*Pounds.*	*Pounds.*
50	Forsyth, Mont.	35	1,066	68	41	27	36	62	26
25	do	35	1,088	75	43	32	35	66	29
51	do	38	942	66	34	32	37½	51	16
	Grand average	36	1,020	68	39	29	36½	58	22

TABLE 21.—*Range cows in transit over 36 hours*—Continued.

Number of head.	Point of origin.	Fill at market.	Total time in transit.	Total shrinkage.		Remarks.
				Before fill.	After fill.	
		Pounds.	*Hours.*	*Pounds.*	*Pounds.*	
50	Forsyth, Mont	36	71	103	67	Drifted 18 miles in 2 days. Had medium fill.
25	.....do	37	70	110	72	Drifted 18 miles in 2 days. Coarser cows than previous shipment.
51	.....do	35	75½	85	50	Drifted 50 miles. Had no feed or water on shipping day.
	Grand average	36	72½	97	61	

On October 6 there was a shipment, not shown in the table, of 270 mixed range cattle from Walker, S. Dak., to Chicago. These cattle came from the Standing Rock Indian Reservation and were handled exactly the same as the shipments of steers from the same place, a record of which is found in Table 20. These were high-grade Hereford and Shorthorn steers and cows, and averaged 1,124 pounds in weight. There were 145 dehorned 3-year-old steers and 53 spayed heifers that would have classed as "choice" on the Chicago market. They showed excellent quality, far above the average, and were extremely fat for range cattle. The other 72 head were good. The whole bunch had a medium or average fill when loaded. They were shipped in feed-and-water cars and had an excellent run to Chicago, being in transit but 53 hours. Their shrinkage was 57 pounds per head, as compared with 70 pounds for the heavy steers in Table 20 and 61 pounds for the cows in Table 21.

MIXED RANGE CATTLE IN TRANSIT OVER 36 HOURS.

Table 22 presents the data secured from the shipping of mixed cattle from Glendive, Mont., to the Chicago market. All of these cattle were rounded up three days before shipping, were thrown together, and driven 40 miles in two days. They were grazed but four hours each day, and were penned the night before shipping and given hay and water. They were taken off feed at 5 a. m., were cut out and put in loading pens, and had water before them until two hours before loading, but they drank very little. No feed was given them and they were loaded at 2.30 p. m. The handling from the time they were rounded up until they were sold was exactly the same for all lots. The cattle were in transit 32 hours to Staples, Minn., took a fill there of 28 pounds each, leaving a shrinkage of but 18 pounds per head. During the second stage of the journey they were in transit 36 hours and shrank 24 pounds, of which they regained 21

pounds by fill at Chicago, leaving a net shrinkage of but 3 pounds for the second stage. The grand average net shrinkage for the whole period of 68 hours was but 21 pounds per head.

TABLE 22.—*Mixed cattle in transit over 36 hours.*

Number of head.	Point of origin.	Time in transit, first period.	Average weight at point of origin.	Shrinkage, first period.		Average fill, first period.	Time in transit, second period.	Shrinkage, second period.	
				Before fill.	After fill.			Before fill.	After fill.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Hours.*	*Pounds.*	*Pounds.*
51	Glendive, Mont.	32	833	39	10	29	38	25	4
43	do	32	1,381	51	29	22	35	22	[1] + 6
43	do	32	1,100	48	13	35	35	28	4
43	do	32	993	47	21	26	35	20	11
	Grand average	32	1,066	46	18	28	36	24	3

Number of head.	Point of origin.	Fill at market.	Total time in transit.	Total shrinkage.		Remarks.
				Before fill.	After fill.	
		Pounds.	*Hours.*	*Pounds.*	*Pounds.*	
51	Glendive, Mont.	21	70	25	14	Driven 42 miles in 2 days. Grazed 4 hours a day.
43	do	28	67	51	23	Do.
43	do	24	67	41	17	Do.
43	do	9	67	41	32	Do.
	Grand average	21	68	42	21	

[1] Gain in weight instead of a shrinkage.

There were three shipments of mixed cattle from Dickinson, N. Dak., to the St. Paul market that are not shown in the tables, as complete records on them were not secured. They should have run into St. Paul within 30 hours, but they were delayed for various reasons, in one case a drawbar pulled out, so that the cattle had to be unloaded and fed in transit. They were 41 hours in transit. The unloading took place at Staples, Minn., and the cattle were on feed 16½ hours before reloading.

One of these shipments was of 28 head of mixed cattle that had been handled carefully before loading and looked extremely well. At market they filled 22 pounds, leaving a net shrinkage of 25 pounds per head, just a little more than the average for the mixed cattle shown in Table 22.

The other two shipments received exceptional maltreatment for cattle of the Northwest. It is seldom that cattle are handled in such a manner in that section. They were rounded up one day. The following day they were driven 20 miles without either feed or water, and were then penned and held all night and until 6 p. m. the follow-

ing day without anything to eat or drink. They had neither feed nor water for 48 hours before being loaded. They naturally looked very bad, almost like shadows, when loaded, and weighed up light. There was 150 pounds of hay put in the racks of each car at Dickinson, and the cattle stayed on feed and water 16½ hours at Staples, Minn., where they took an enormous fill. The weights at Staples were not secured, as the cattle were supposed to run into St. Paul without being unloaded.

These cattle, instead of showing a shrinkage in transit weighed from 2 to 5 pounds heavier after taking a fill at market than at Dickinson, N. Dak. This was without doubt due to the abnormal condition they were in when loaded. This method of handling cattle is to be condemned, as it is cruel to the animals in the first place and unprofitable for the shipper as well. Cattle shipped under such conditions look bad when they arrive at market and show the large fill to such an extent that their selling price is much lower than for animals with an average fill. This is an instance where the large fill at market is undesirable.

DETAILS OF WORK IN SOUTHWEST.

The pastures throughout Texas had been very short during the whole year of 1910. In fact, the grass was so scant in some parts that many cattle would have died had there not been a fair crop of mesquite beans upon which to feed. Because of the drought very little grass grew along the trails over which cattle traveled to the loading pens, and the cattle driven along these trails usually arrived at the loading point with a very poor fill, and consequently weighed up light at the point of origin. Some of these cattle were so empty when first weighed that the shrinkage in transit was very small, and sometimes was completely overcome by the fill taken at the market. A season of this kind is conducive to a small shrinkage. While the results obtained from the shrinkage work of 1910–11 (shown in Part I of this bulletin) are applicable to a dry or droughty year, they do not represent the normal shrinkage under average conditions. For this reason, it was decided to duplicate the work of 1910 in the Southwest.

During the winter of 1910–11 there were frequent rains, and the grass in Texas was good the following summer. This grazing season was about a normal one for Texas, and the results obtained from the shrinkage work may be taken as an average. Most of the cattle shipped in the fall were either in good flesh or fat. There were a few exceptions, of course, but taking the cattle that were weighed as a whole, they were about the average of what go to market from Texas during a normal or average year.

Cattle from Texas may have been driven anywhere from 1 to upward of 100 miles to the railroad for shipping. As a rule they are driven from 15 to 20 miles each day and then grazed along the trail for a few hours, and this procedure is kept up until the shipping pens are reached. Few cattlemen feed their cattle on arrival at the shipping pens before loading. Many prefer not letting their cattle have any water, or if they do, to let them drink little, as it is said they do not stand up well in the cars. The racks of the cars are seldom filled with hay for the stock to eat while in transit, as some shippers claim that the cattle will eat little of it, while others assert that if the cattle do eat much hay it will diminish their hunger to such an extent that they will not take a good fill at market. However, this was found to be the case in very few instances. The discussion of this will be taken up later.

Unfortunately for the completeness of the work, in the early fall of 1911 practically the entire cattle yards of the Fort Worth Stock Yards Co. burned, destroying all the scales in the yards but one. In consequence of this the weighing of stock after sale caused such a congestion near the scales that it was impossible to weigh the range cattle on arrival at market. For this reason the fill of the animals could not be determined, but as the sale weight was secured the net shrinkage on each shipment was ascertained. As it is only the net shrinkage which is absolutely important to the cattlemen, the value of the work was not materially lessened.

RANGE COWS IN TRANSIT LESS THAN 24 HOURS.

Table 23 presents the weights and shrinkage data obtained on 1,307 range cows that were in transit to market less than 24 hours. A study of the table reveals the fact that the shrinkage varied considerably with the different lots, there being a range of 26 to 60 pounds on different shipments.

The small shrinkages invariably occurred with the cattle that had either been driven a long way to load without having sufficient time to graze along the way, or that had been held for several hours without feed or water before weighing. The cattle which showed a large shrinkage were usually ones which had taken a good fill before weighing, or had failed to fill at market, though sometimes it was due to a poor run to market. All of the shipments presented in this table received good runs to market, and the average shrinkage for all the animals, 34 pounds per head, will give a good idea of the shrinkage to be expected from shipping cattle a distance of about 325 miles, or a 22-hour run.

The shipment from Colorado, Tex., of 31 head of cows, which were in transit only 19½ hours and shrank 60 pounds, was driven but 4

miles from the pasture to the loading pens, and had a medium fill. Evidently they failed to fill at the market.

The 293 head from Colorado, Tex., forming the last item in the table, were all Mexican cows which had been on grass in Texas between 60 and 90 days. They were very poor, just frames, when brought in, and had put on flesh wonderfully fast. They were driven but 9 miles and showed a shrinkage of 46 pounds per head.

TABLE 23.—*Range cows in transit less than 24 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination after fill.	Average net shrinkage.	Remarks.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	
27	Odessa, Tex	23½	989	952	37	Had a medium fill when loaded.
28	do	21	868	809	59	Had grass until loaded.
520	do	23	987	961	26	Driven 25 miles in 2 days. Grass until loaded.
31	Colorado, Tex	19½	868	808	60	Driven 4 miles to loading pens. Had a medium fill.
202	Odessa, Tex	23	861	834	27	Trailed 25 miles to pens. Plenty of grass and water. Average fill.
61	do	23	879	832	47	
145	do	23½	876	850	26	Trailed 2 days to loading pens. Grass, but no water before loading.
293	Colorado, Tex	16½	606	560	46	Trailed 9 miles. Mexican cows grazed in Texas for 90 days.
	Grand average	22	860	826	34	

The grand average of Table 23 shows the run to be of 22 hours' duration, the average weight to be 860 pounds, and the net shrinkage to be 34 pounds. In other words, the shrinkage on cows of the Southwest for an average year was found to be 4 per cent of their live weight when they were in transit 22 hours only.

RANGE COWS IN TRANSIT OVER 24 HOURS.

In Table 24 are the weights of 17 shipments of cows, totaling 1,383, from Odessa, Tex., to the Fort Worth market. This run should be made within 24 hours, and in Table 23 are shown several shipments which made the run in less than 24 hours, but the time required for the shipments shown here varied from 24½ to 33½ hours. These cattle were chiefly grade Herefords and Shorthorns, though some were of common breeding. Practically all of them were in good condition, and some were really fat for grass cattle. The weather was good during the whole fall, though some of the days were hot. No storms or "northers" came during the time these cattle were being shipped. The animals ranged in weight from 817 to 1,002 pounds at the loading point, averaging 907 pounds. The shrinkage

on the different shipments varied greatly, ranging from 4 pounds to 64 pounds per head.

The first shipment of 25 cows was driven only 7 miles and was grazed before loading, so they had a good fill. They were in transit 28½ hours but did not have a good run. The result was that they shrank 64 pounds per head. The third shipment shrank but 4 pounds each. The fourth shipment of 80 head of cows was in transit 31 hours. These cattle had a very slow run, but still shrank only 6 pounds each. They evidently took a big fill at the market.

The shipment of 291 head of cows was driven 110 miles from the ranch to the railroad. They were on the road seven days, being trailed about 16 miles a day and grazed. However, the trip was a hard one because of its great length. The cattle were grazed the day before shipping but had neither feed nor water the day they were shipped, and as they were not loaded until 3 p. m. they looked hollow and were empty. The shrinkage on these cattle was only 16 pounds per head, which was of course due to the poor fill they had when loaded. As there are many cattle loaded in Texas under the same conditions this shipment is an important one and may be taken as an average for shrinkage on such shipments.

The difference between the shrinkage of cattle loaded under the above conditions and of cattle loaded where they have had an opportunity to graze and drink before loading is clearly shown by the comparison of this shipment with the next one below. These 27 cattle were on the road to the loading pens two days, but had grass and water until loading time. They were in transit to market 24½ hours, the same time as the 291 head, and were handled the same way after loading, but they shrank 51 pounds per head, as compared with 16 pounds for the previous shipment. The greater part of this shrinkage of 51 pounds was merely the loss of the fill taken before loading.

The last shipment shown in the table was composed of 29 cows in medium flesh. These cattle had a very poor run to market, requiring 33½ hours to make the trip. Their shrinkage was 58 pounds per head. As their fill taken at market was not secured it can not be said just how much of this large shrinkage was due to the very poor run and how much to a lack of fill at the market.

The grand averages for the 1,383 cows show their average weight to be 907 pounds, the time in transit to market to be 27 hours, and their net shrinkage to be 32 pounds per head. This is but 3.5 per cent of their live weight.

TABLE 24.—*Range cows in transit over 24 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination after fill.	Average net shrinkage.	Remarks.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	
25	Odessa, Tex.	28½	1,002	938	64	Trailed 7 miles carefully.
25	do.	28½	876	836	40	
27	do.	25	907	903	4	Had a poor fill when loaded.
80	do.	31	910	904	6	
141	do.	29	973	929	44	Trailed 2 days. Plenty of grass and water on road to pens.
50	do.	24½	974	924	50	
29	do.	24½	905	866	39	
255	do.	24½	969	943	26	
29	do.	27	885	850	35	Driven 8 miles. Had neither feed nor water before loading.
145	do.	26	895	849	46	
291	do.	24½	844	828	16	Driven 110 miles in 7 days to loading pens. No feed or water 20 hours before.
27	do.	24½	1,001	950	51	On road 2 days. Plenty of grazing. Had medium fill.
56	do.	24½	885	845	40	Driven 8 miles. Looked well and had a good fill.
27	do.	25	817	774	43	Do.
60	do.	33½	868	827	41	Driven 35 miles in 3 days. Had medium fill. Poor run to Fort Worth.
87	do.	30½	852	808	44	Trailed 90 miles in 6 days. Medium fill.
29	do.	33½	876	818	58	Had a poor run to market.
	Grand average.	27	907	875	32	

A comparison of Table 23 and Table 24 shows that the shrinkage on cows that received a normal run to market is much more uniform than for those that were delayed in transit or that just made slower time. An average of all the shipments of the cows that were from 1 to 10 hours longer in transit than an average good run from the same points shows an increased shrinkage of but 4 pounds, but the shrinkages were much more variable. In some cases, however, a large shrinkage could only be attributed to delayed transportation. The average shrinkage on 983 cattle from Odessa, Tex., in Table 23 that were in transit less than 24 hours was 28 pounds per head, while the shrinkage on those over 24 hours in transit was 32 pounds per head. The cattle were practically the same size in each case, and were handled under similar conditions.

A comparison of the shrinkage of range cows in the Southwest in transit under 36 hours can be made with the shrinkage of range cows in the Northwest for the first period of their journey, averaging 36 hours (see Table 21). In the Northwest the shrinkage for the first 36 hours was 39 pounds per head, while in the Southwest the shrinkage was 32 pounds. The shrinkage on southwestern cows for the short runs (Table 23) was 34 pounds. These results are seen to be very uniform when we consider the live weights of the

animals. Thus, the proportion of shrinkage to live weight of the southwestern cows for the short runs (average 22 hours) was 4 per cent and for the longer runs (average 27 hours) 3.5 per cent. The proportion for the northwestern cows for the first portion of their journey (36 hours) was 3.82 per cent. The grand average percentage for all is, therefore, practically the same.

MIXED RANGE CATTLE IN TRANSIT LESS THAN 24 HOURS.

Ranchmen like to cut out the cattle that are to be shipped in such manner that the different classes will not be mixed in the cars. This can not always be done, however, and animals of the various classes are sometimes indiscriminately thrown together, giving rise to mixed shipments. These consignments of mixed cattle do not always ship well, as the large ones squeeze and trample the small or the weak ones, and if the journey is very long there may be several dead or crippled animals in a car when it arrives at the market. The shrinkage on these mixed shipments of cattle may not be greater than on other classes of live stock, but because of the losses in shipping more lawsuits arise from this class of stuff than any other, and consequently the railroad companies have an aversion to it.

In Table 25 are displayed the data from shipments of mixed range cattle aggregating 849 head that were in transit less than 24 hours. All of these cattle originated from near Colorado, Tex., or Odessa, Tex. They, of course, varied in weight more than any other class of cattle, this variation depending largely upon the percentage of calves in the shipment. The average weights of the different shipments ranged from 415 pounds for a bunch of Mexican heifers to 936 pounds for a shipment of cattle from Odessa, Tex. The time in transit did not vary greatly, being 17 hours to 22½ hours.

There is a greater variation in the shrinkage for this class of animals than any other. In the table this ranged from a gain in weight of 2 pounds per head in a shipment containing 17 cows and 23 calves to a loss in weight of 71 pounds per head on another lot. The 40 cattle which averaged 2 pounds heavier at Fort Worth than they did at Colorado, Tex., were fat, but they had no feed or water before being loaded and were very empty. They took a good fill at market, which more than overcame the light shrinkage in transit.

The consignment from Colorado, Tex., of 29 cattle which shrank 71 pounds each had been pastured but 3 miles from town, and was a mixture of steers and cows. They were taken direct from the pasture to the loading pens, and were there given a feed of green kafir corn before being loaded and weighed. This gave the cattle an abnormal fill and also had a bad effect on them, as is shown by the fact that they were in transit but 21 hours and yet shrank 71 pounds per

head. An average of all the shipments of Table 25 shows a shrinkage of 26 pounds per head.

The 68 bulls from Odessa, Tex., weighed 1,124 pounds each and shrank 38 pounds per head, or 12 pounds more than the average for all the cattle. The five cars of steers, 139 head, shrank but 19 pounds each, or 7 pounds less than the average. The shipment of 40 Mexican heifers from Colorado shrank 26 pounds each. These heifers had been shipped in from Mexico 60 days previous and put on pasture. While they had gained in weight while on pasture, they were still poor when shipped.

The grand average of all the 849 head of cattle showed them to have been in transit 21 hours to market, to have had an average weight of 783 pounds, and to have lost 26 pounds in weight from shipping.

TABLE 25.—*Mixed range cattle in transit less than 24 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination after fill.	Average net shrinkage.	Remarks.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	
32	Colorado, Tex.	18	722	722	0	
47	Odessa, Tex.	23½	519	497	22	These were 14 cows and 33 calves.
84	do.	19½	950	904	46	These were 65 cows and 19 bulls.
92	Colorado, Tex.	17½	739	714	25	Driven 9 miles slowly. Had medium fill.
40	do.	17½	508	510	[1] +2	These were 17 cows and 23 calves. Poor fill at Colorado.
28	Odessa, Tex.	24	928	910	18	
28	do.	24	936	913	23	
179	do.	23½	846	820	26	Cattle were "worked" 2 days at ranch. On road 2 days to pens.
43	Colorado, Tex.	18½	521	496	25	The calves were fat, but the cows were poor and weak.
29	do.	21	886	815	71	Driven but 3 miles and fed green kafir corn before loading.
68	Odessa, Tex.	23	1,124	1,086	38	3 cars of bulls.
139	do.	19½	750	731	19	5 cars of steers.
40	Colorado, Tex.	17	415	389	26	Thin 2-year-old Mexican heifers.
	Grand average.	21	783	757	26	

[1] Gain in weight instead of a shrinkage.

MIXED RANGE CATTLE IN TRANSIT OVER 24 HOURS.

The shrinkage on mixed range cattle in transit to market over 24 hours is presented in Table 26. All of the 150 head in the table originated near Odessa, Tex., and are shipments which made poor time to market. These shipments should have gone through within 24 hours, but for various reasons were longer. The difference in shrinkage between these cattle and those from Odessa that did make the run within 24 hours may be considered due to delay, etc. Each shipment was made up of but a single car, and was made up largely

of 2-year-olds, cows, and bulls, with a few steers mixed in. There were very few calves in the shipments. The cattle were in transit from 24½ to 31 hours, and ranged from 614 to 878 pounds in weight. The shrinkage was not so variable with these cattle as with those in transit less than 24 hours.

It will be noticed that the shipment of 30 head, although the heaviest cattle, shrank the least in shipping. This is readily explained by the fact that they were started from the ranch at 3 o'clock in the afternoon and were driven 18 miles to the loading point, arriving there the next afternoon, where they were penned. They were loaded and weighed at 6 p. m., having had neither feed nor water since they left the ranch 27 hours previous. They were consequently very empty and could not shrink as much as cattle under average conditions. Then, too, they were in transit but 24½ hours and took a fairly good fill at market.

The shipment of 26 head of cattle had been held on good pasture within 6 miles of the loading pens for several days previous to shipping. They were penned at 11 a. m. and held in the pens until 5 o'clock in the afternoon without feed or water. They were then weighed, but were not loaded until 10 o'clock that night. They had a poor fill when weighed and shrank only 21 pounds after the fill at market.

On the other hand the two shipments of 28 head each had been trailed a long distance and were watered just previous to weighing. The result was a big shrinkage with each of them—75 pounds per head in one case and 55 pounds per head in the other. The latter shipment had been trailed 52 miles.

The grand average of all the shipments shows they were in transit 29 hours, their weight was 751 pounds, and their shrinkage was 42 pounds each. This is 5.6 per cent of their live weight.

TABLE 26.—*Mixed range cattle in transit over 24 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination after fill.	Average net shrinkage.	Remarks.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	
38	Odessa, Tex	31	614	573	41	
26	do	29	814	793	21	Driven 6 miles and held all day without feed or water.
28	do	29	782	707	75	
30	do	24½	878	859	19	Driven 18 miles. Had no feed or water for 26 hours before loading.
28	do	31	711	656	55	Driven 52 miles in 4 days. Were watered before loading.
	Grand average	29	751	709	42	

The average shrinkage per head on the mixed cattle from Odessa that were in transit less than 24 hours was 28 pounds. There were 573 head of these cattle shown in Table 25. A comparison of these with the shipments of Table 26 discloses the fact that the cattle in transit 29 hours shrank 12 pounds more than those in transit less than 24 hours. As all of them should have made the trip within the 24-hour limit, the excess shrinkage of 12 pounds per head may be attributed to the poor or slow transportation.

RANGE CALVES IN TRANSIT TO MARKET.

The shrinkage on calves has been found to be more uniform than on any other class of cattle shipped. Regardless of the weather, grazing, and other factors which seriously affect the shrinkage on large cattle, the variation in the shrinkage of calves is small. This is because the cows are always driven to the loading pens with the calves, and the calves stay with their mothers until time to cut them out to load. Their fill therefore is of milk, which is usually small in amount, and the subsequent shrinkage is likewise small. The fill at market also is not large, being but a few pounds as a rule, hence the uniformity in the results obtained.

On the 211 calves in Table 27 there is a shrinkage of 11 to 13 pounds for the different shipments. This gave an average of 12 pounds, or 4.8 per cent of their live weight. It is seen, therefore, that while the shrinkage is small it is uniform and in about the same proportion to the weight of the animals as with grown cattle.

TABLE 27.—*Range calves in transit less than 36 hours.*

Number of head.	Point of origin.	Time in transit.	Average weight at point of origin.	Average weight at destination after fill.	Average net shrinkage.	Remarks.
		Hours.	*Pounds.*	*Pounds.*	*Pounds.*	
73	Odessa, Tex	28½	216	205	11	Driven 7 miles. Loaded without feed or water.
73	.....do	21	253	240	13	
65	Colorado, Tex	19½	271	260	11	Driven 11 miles in 2 days. Stayed with cows until loaded.
	Grand average	23	246	234	12	

SUMMARY.

In Table 28 is presented a summary of the work of 1911. About 5,000 animals were weighed in securing these data. The grazing season of 1911 was about the average for good years, or a little better than the average when all years are considered. The results secured

are therefore a good indication of what may be expected during a normal season.

In column 1 is shown the number of shipments of each of the various classes of cattle. Column 2 shows the number of animals in each of these classes. The third column shows the average weight of the cattle at the point of origin. It is seen that the animals from the Northwest are heavier than those from the Southwest; the southwestern cows weighed from 860 to 907 pounds, while the northwestern cows averaged 1,020 pounds. The large difference between the weights of the mixed cattle from the two sections is partially due to the larger proportion of calves among the mixed cattle from the Southwest.

The burning of the cattle yards and all of the scales but one at Fort Worth prevented the cattle from being weighed on arrival from the ranch; hence their shrinkage in transit and fill at market can not be shown. The net shrinkage, however, is shown for all of the shipments.

In the fourth column is shown the variation in the gross shrinkage. This variation of shrinkage for the different shipments in each class was not great, being 18, 25, and 26 pounds, respectively, for the range steers, cows, and mixed cattle from the Northwest. The average gross shrinkage, as recorded in column 5, was 111, 97, and 42 pounds, respectively, for the same classes of cattle.

The fill taken at market was very uniform for all classes, the greatest variation being 19 pounds for the mixed cattle. The average fill for the steers, cows, and mixed cattle from the Northwest was 41, 36, and 21 pounds, respectively.

The last two columns of the table present figures for the range and the average net shrinkage for the various classes of cattle. It is of interest to note how much more uniform the shrinkage was on the different shipments of cattle from the Northwest as compared with those of the Southwest, the range of net shrinkages being quite wide with the shipments from the Southwest. The range of net shrinkage on northwestern cows was from 65 to 83 pounds, a difference of 18 pounds, while with the southwestern cows it was 26 to 60 in one case and 4 to 64 in another.

The average net shrinkage on all of the cattle was as follows: Calves, 12 pounds; northwestern range steers in transit 68 hours, 70 pounds; cows from the Southwest in transit less than 24 hours, 34 pounds, and those in transit from 24 to 36 hours, 32 pounds. The mixed cattle of the Southwest shrank 26 pounds per head when in transit less than 24 hours and 42 pounds when in transit from 24 to 36 hours, while the mixed cattle of the Northwest shrank but 21 pounds per head while in transit for about 72 hours.

TABLE 28.—*Summary of northwestern and southwestern work of 1911.*

Description.	Number of shipments.	Number of cattle.	Average weight at origin.	Gross shrinkage.		Fill at market.		Net shrinkage.		Ratio of shrinkage to live weight at origin.
				Range.	Average.	Range.	Average.	Range.	Average.	
			Pounds.	*Pounds.*	*Lbs.*	*Pounds.*	*Lbs.*	*Pounds.*	*Lbs.*	*Per ct.*
Southwestern range calves en route less than 36 hours	3	211	246	.....	.....	.....	.....	11–13	12	4.9
Northwestern range steers en route over 36 hours	5	730	1,193	106–124	111	40–41	41	65–83	70	6.0
Southwestern range cows en route less than 24 hours	8	1,307	860	.....	.....	.....	.....	26–60	34	4.0
Southwestern range cows en route 24 to 36 hours	17	1,383	907	.....	.....	.....	.....	4–64	32	3.6
Northwestern range cows en route over 36 hours	3	126	1,020	85–110	97	35–37	36	50–72	61	6.0
Southwestern mixed range cattle en route less than 24 hours	13	849	783	.....	.....	.....	.....	+2[1]–71	26	3.3
Southwestern mixed range cattle en route 24 to 36 hours	5	150	751	.....	.....	.....	.....	19–75	42	5.6
Northwestern mixed range cattle en route over 36 hours	4	180	1,066	25–51	42	9–28	21	14–32	21	2.0

[1] Gain in weight instead of a shrinkage.

CONCLUSIONS.

1. A big shrinkage may be caused by one of three things, viz., (*a*) A big fill at the point of origin when weighed; (*b*) failure to fill at destination; or (*c*) a poor, slow run to market.

2. The shrinkage for the first 24 hours is always greater than for any succeeding period of the same length, and the rate of shrinkage is also much greater for the first 24-hour period than for any succeeding period.

3. Cattle of the Northwest will shrink from 5 to 6 per cent of their live weight while in transit from 36 to 72 hours.

4. There is practically no difference in the rate of shrinkage of spayed heifers and steers of the same size and quality when shipped under similar conditions.

5. The shrinkage of cattle from Montana and the Dakotas to the Chicago market was not as great as usually predicted by the cattlemen of that section.

6. The careful handling of cattle while driving to the loading pens, and the feeding of some good bright hay just before loading is profitable for the shipper.

7. Too great a fill of water just previous to loading should be avoided, the condition of the cattle should approach the normal as near as possible when ready to ship.

8. The practice of holding cattle off feed and water for a long period before shipping with the idea that they will take an exceed-

ingly large fill at market is a poor policy, as it is neither profitable nor humane.

9. The shrinkage is more uniform with calves than with any other class of animals. Their shrinkage, however, maintains about the same ratio to their live weight as does the shrinkage on grown animals shipped the same distance.

10. There was a smaller percentage of calves shipped from the ranges of the Northwest than from the Southwest.

11. An average for all of the shipments shows that during the second period of 36 hours in transit the cattle shrank about 40 per cent less than they did during the first 36-hour period.

IV. SUMMARY OF THREE YEARS' SHRINKAGE WORK.

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GENERAL STATEMENT.

The cattle used in making this investigation were raised in different parts of the West. The range cattle work was carried on in the various Western States from Texas to Montana, and the work with the fed cattle was confined chiefly to the States of the Middle West. No discrimination was made against any section, but the work was done where the conditions were most favorable for it. There were many things that had to be considered, but the one of most importance was the scales used in making the weighings. There were no platform scales that could be used in weighing cattle on the hoof in the range country, so the railroad track scales had to be used. Great care was taken in making all weighings that the data should be accurate. The officials of the railroads realized the importance of the work and gave whatever aid was asked of them. The Texas and Pacific road even went so far as to purchase scales for weighing cattle on the hoof and placed them in the alleys of two of their important loading pens, so that all cattle would have to pass over them before being loaded. These scales were large, being 14 by 42 feet, so that a whole car of cattle could get on them at one time without crowding. They were set on a solid concrete foundation and were very accurate. The installation of these scales at Colorado, Tex., and Odessa, Tex., aided very materially in securing the shrinkage data on cattle from the Southwest. The burning of the cattle yards at Fort Worth in 1911 prevented the weights of cattle being taken on arrival, so the fill the animals took at market could not be ascertained for that year.

The shrinkage of cattle in transit is such a variable factor that no one can say definitely how much it will be during a journey, but by the use of very large numbers of cattle an average shrinkage will be obtained which may be used as a basis for estimating the amount of shrinkage on cattle shipped under similar conditions.

The figures for any class of cattle of the Southwest will be seen to vary widely for the years of 1910 and 1911 because of the great dissimilarity in the two seasons, which caused a difference in the grazing, the fatness of the animals, scarcity of water, etc. If the figures

of this bulletin are used, care should be taken to look up the results for shipments of cattle that were made under conditions similar to the ones which are to be used for comparison. The results shown in Part I are typical of a very droughty year in the Southwest, and therefore could not be used in estimating the shrinkage of cattle shipped from Texas during a good grazing season. The figures shown in Part III should be used for such. Nor would they be applicable for estimating a shrinkage on cattle in the Northwest.

The range cattle of the Southwest principally came from Texas, although there were some from Arizona and Mexico. From the Northwest the range cattle came chiefly from the Dakotas, Montana, Wyoming, and Nebraska. It is interesting to note that in the work of the Northwest there is not a shipment of calves recorded, while they were quite common in the Southwest. Texas has built up a reputation for calves as feeders and stock cattle, while in the Northwest they are kept on the range until they are 2 to 4 years old. The northwestern cattle are heavier, usually fatter and shrink more per head in shipping than do Texas cattle, but when the length of the journey to market is considered there is very little difference in the shrinkage.

When care is used in trailing the cattle to the loading pens, not driving them too fast nor too far in a day and giving them five or six hours a day to graze on the way, long distances may be covered with no apparent injury to the cattle. On arrival at the pens it is well to give the animals a light feed of hay with a little water, or allow them to graze a short time before loading them, unless the grass is very luxuriant. An excessive fill of water or green fodder or grass just before loading is not good for the cattle, as it may cause them to scour in transit; then, too, they will not stand up as well in the cars. The scouring may affect the intestinal tract to such an extent that the cattle will not take a good fill at the market.

All of the corn-fed cattle were finished during the winter or early spring months. While none of them had to be driven long distances to the loading pens, the roads were often in such bad condition because of snow and ice as to make the trip laborious and hard on the cattle. The cattle were usually fed and watered a short time before loading, and many times hay was put in the racks of the cars. The treatment they received in this respect was far better than that which was accorded to the range cattle. There is no doubt that the feed given the cattle before loading increased the shrinkage in transit, but that does not mean that it was not beneficial to the cattle and profitable to the shipper, because the cattle would naturally look better for having been handled this way, and they would sell at the market at a price which would more than offset the increased shrinkage. More care is always taken by the feeder than by the ranchman in

preparing cattle for shipping. This is natural, for conditions are such that it is much easier for him to do this; then, too, his stock is more valuable per pound than grass cattle, and the increased shrinkage on them entails a greater financial loss.

The feeders of beet-pulp cattle have made a closer study of the shrinkage of their stock than any other class of feeders. This is probably because the operators of sugar mills feed large numbers of cattle and can therefore be better equipped to do the weighing. It must be conceded, however, that usually they are more progressive than the average farmer or stockman. The cattle fed on beet pulp were always taken off the pulp ration about 24 hours previous to shipping and put on a dry ration of hay and grain. This always caused a shrinkage in weight, varying from a small amount to as high as 68 pounds per head. This shrinkage for the day before shipping naturally decreased the shrinkage which the cattle would undergo while in the cars. Even then, however, the shrinkage in transit on the pulp cattle was always large.

Feeders who finish their cattle on silage follow practically the same plan in regard to giving the cattle dry hay or fodder for the 24 hours preceding shipment. It is not uncommon, also, for the water to be cut off from the silage-fed cattle for about 12 hours before loading. This naturally causes the cattle to undergo a shrinkage just previous to shipping and thus favors a smaller shrinkage in transit.

Table 29 follows, showing a general summary of all the shrinkage work recorded in this bulletin.

TABLE 29.—*General summary of three years' shrinkage work.*

Class.	Number of shipments.	Number of cattle.	Average weight at origin.	Gross shrinkage.		Fill at market.		Net shrinkage.		Ratio of shrinkage to live weight at origin.
				Range.	Average.	Range.	Average.	Range.	Average.	
			Lbs.	*Pounds.*	*Lbs.*	*Pounds.*	*Lbs.*	*Pounds.*	*Lbs.*	*Per ct.*
Range steers in transit less than 36 hours	2	197	794					19- 55	29	3.65
Range steers in transit 36 to 72 hours	8	882	1,186	57-124	89	13-41	25	26- 83	64	5.40
Range steers in transit over 72 hours	2	169	1,116	85- 99	88	2-36	27	49- 97	61	5.47
Range cows in transit less than 24 hours	15	1,724	838	33-105	60	5-88	30	[1]+12- 60	30	3.58
Range cows in transit 24 to 36 hours	21	1,551	896	38-129	70	9-70	39	[1]+ 5- 64	31	3.46
Range cows in transit 36 to 72 hours	4	275	1,034	90-110	96	36-56	46	34- 72	50	4.84
Range cows in transit over 72 hours	3	177	1,010	49- 85	70	28-35	30	21- 56	40	3.96
Mixed range cattle in transit less than 24 hours	21	1,511	700	19- 84	37	1-56	22	[1]+12- 71	15	2.14
Mixed range cattle in transit 24 to 36 hours	17	872	848	27-118	72	[2]−8-55	18	19-114	54	6.37

[1] The plus sign (+) indicates a gain in weight instead of a shrinkage. Attention is called to the 16 shipments of range calves, wherein the ratio of shrinkage to live weight (last column of table) is unduly low, because the great majority (13) of the shipments occurred in 1910, the droughty year. The 3 shipments in 1911, the normal year, gave a ratio of 4.9 per cent.

[2] The minus sign (−) indicates a loss in weight instead of a fill.

TABLE 29.—*General summary of three years' shrinkage work*—Continued.

Class.	Number of shipments.	Number of cattle.	Average weight at origin.	Gross shrinkage.		Fill at market.		Net shrinkage.		Ratio of shrinkage to weight at origin.
				Range.	Average.	Range.	Average.	Range.	Average.	
			Lbs.	*Pounds.*	*Lbs.*	*Pounds.*	*Lbs.*	*Pounds.*	*Lbs.*	*Per ct.*
Mixed range cattle in transit 36 to 72 hours.	10	622	954	25–110	76	9–47	39	[1]+ 1– 51	37	3.88
Mixed range cattle in transit over 72 hours..	6	988	729	42– 96	80	16–40	29	7– 71	51	7.00
Range calves in transit less than 24 hours....	8	773	185	[1]+[2] 1– 17	[2] 6	[2] 6–13	[2] 7	[1]+14– 13	[1]+ 1	[1]+ .59
Range calves in transit over 24 hours.....	8	772	193	[3] 6– 11	[3] 6	[4]—[3] 3–17	[3] 11	[1]+ 9– 13	[1]+ 5	[1]+2.45
Mixed corn-fed cattle in transit less than 24 hours.....	4	164	1,303	59– 95	67	4–48	16	20– 64	51	3.91
Mixed corn-fed cattle in transit 24 to 36 hours.....	59	1,853	1,167	47–128	85	19–52	37	18– 88	48	4.11
Mixed silage-fed cattle in transit less than 24 hours.....	14	666	1,168	46–128	76	6–97	52	[1]+ 7– 67	24	2.05
Mixed silage-fed cattle in transit 24 to 36 hours.....	4	169	1,204	84–121	101	50–64	58	27– 75	43	3.57
Cottonseed-meal-fed steers in transit 30 to 48 hours.....	10	1,296	1,074	61– 76	72	9–21	14	41– 73	58	5.40
Beet-pulp-fed cattle in transit 60 to 120 hours.	10	1,009	1,390	90–111	100	11–26	25	16– 99	75	5.40
Beet-pulp-fed cattle in transit 38 to 120 hours.	32	2,614	.....	.....	.....	.....	.....	[1]+ 5–132	54	.....

[1] The plus sign (+) indicates a gain in weight instead of shrinkage. Attention is called to the 16 shipments of range calves, wherein the ratio of shrinkage to live weight (last column of table) is unduly low, because the great majority (13) of the shipments occurred in 1910, the droughty year. The 3 shipments in 1911, the normal year, gave a ratio of 4.9 per cent.

[2] Data on 635 head.

[3] Data on 699 head.

[4] The minus (—) indicates a loss in weight instead of a fill.

NOTE.—The data were incomplete on the shipments where blank spaces are found. The cattle mentioned in the text but not included in the tables are not shown in this table, nor are the 7 shipments of 1,310 cattle presented in Table 5.

CONCLUSIONS.

There is no way of entirely preventing shrinkage in the shipping of cattle, but by judicious care in handling and feeding the cattle just previous to shipping the shrinkage may be lessened. If cattle are to be in transit for 24 hours or longer it is a good plan to feed about two bales of nice bright hay for each carload a few hours before loading.

The reader should understand that the three tests in this bulletin are not directly comparable, but they do in a general way give a good idea of what will occur in shipping cattle under various conditions. The difference in the shrinkage of the cattle of Parts I and III was chiefly due to the season and factors which are influenced by it. During the season of 1910 most of the shrinkage of the cattle occurred during the drive to the loading pens, because there was little grass and water to be secured along the trails and the cattle were so empty when shipped that the shrinkage was small, and the fill taken at market oftentimes overcame it.

When the distance to market is considered, the shrinkage on the cattle from the northwestern ranges was about the same as the shrinkage of Texas cattle during a normal year. The grazing season of 1911 was a normal one over the entire West, so the shrinkages of range cattle for that year are directly comparable.

In Part III the shrinkage on cattle from the Southwest was 34 pounds for cows in transit less than 24 hours; 32 pounds for cows in transit from 24 to 36 hours, and 26 to 42 pounds for mixed cattle in transit for the same periods; while in the Northwest the shrinkage for the first 36-hour period was 39 pounds for cows, 39 pounds for steers, and 18 pounds for mixed cattle. In other words the shrinkage in the Southwest was 3.5 per cent of the live weight for cows and 3.7 per cent for mixed cattle, while in the Northwest the percentage was about 3.3 for an average of all the cattle for the first 36 hours en route.

In Part II the shrinkage for mixed range cattle in transit over 72 hours is seen to be 53 pounds per head, or 5.1 per cent of their live weight, while in Part III the shrinkage on range cattle in transit for the same length of time is 70 pounds for steers, 61 pounds for cows, and 21 for mixed cattle, or an average of 60 pounds per head when all are considered. The range cattle used in Part II were shipped from Wyoming and Montana, while those recorded in Part III were from Montana and the Dakotas. The shrinkage on the latter cattle was 5.9 per cent for the cows and 6 per cent for the steers, which was a little greater than for the cattle recorded in Part II. When all of the cattle from the Northwest are considered which were in transit over 70 hours, the shrinkage ranged from 3.96 to 7 per cent, or an average of about 5½ per cent of their live weight. The shrinkage of all the cattle from the sand hills of Nebraska was about 5.2 per cent of their live weight.

In Part II is shown the shrinkage data on pulp-fed and silage-fed cattle. The pulp-fed cattle shrank very materially when they were put on dry feeds for 24 hours just previous to shipping. In one case this shrinkage was 32 pounds and in another case 68 pounds per head. Despite these large losses in weight just previous to loading, the shrinkage in transit and the net shrinkage at market were greater per head than for any other class of cattle. They did not take as large a fill as might have been expected. The net shrinkage on the pulp-fed cattle was 5.4 per cent of their live weight.

Some very interesting data are found in the table on pulp feeding in Part II. It is shown that the shrinkage on the pulp-fed cattle increased with the length of the journey. The distances and time of shipments in transit from the Colorado feed lots to market were about as follows: To St. Joseph, 520 miles or 57 hours; Kansas City, 580

miles or 60 hours; St. Louis, 825 miles or 70 hours; and Chicago, 1,000 miles or 119 hours. The average shrinkage of all cattle to St. Joseph was 37 pounds; to Kansas City, 55½ pounds; to St. Louis, 68 pounds; and to Chicago, 88¼ pounds.

The silage-fed cattle were usually put on dry feed the day before shipping, and no doubt there was considerable shrinkage on these cattle during this time, although there are no data to confirm this. This would be especially noticeable where the water was cut off from them for 12 hours before shipping, as was sometimes done. All of the silage-fed cattle shrank heavily in transit, but in every case took a large fill at market. The fills taken were so large that the net shrinkage on silage-fed cattle averaged smaller than for any other class of fed cattle.

There was one shipment of 107 head of silage-fed cattle which were held off water but given dry feeds for over 15 hours before shipping, and consequently shrank so little in transit that the fill taken at market overcame the shrinkage and they showed a gain of 7 pounds each. This lowered the shrinkage on the whole class several pounds. The shrinkage on the silage-fed cattle was 29 pounds for those in transit less than 24 hours and 43 pounds for those in transit from 24 to 36 hours. This was equivalent to 2.05 per cent of the live weight in one case and 3.57 per cent in the other.

A glance at Table 29, presenting the general summary of the work, brings out the fact that the weights of about 2,500 head of corn-fed cattle were used in determining the shrinkage on this class. The gross shrinkage is seen to vary widely, ranging from 47 to 128 pounds per head. The fill taken at market varied from 4 to 52 pounds per head. The average fill at market was smaller than for any other class of grown cattle except those fed on cottonseed meal and hulls. The net shrinkage of these cattle was 51 pounds for the steers which were in transit less than 24 hours, and 48 pounds for lighter steers which were in transit from 24 to 36 hours. This was a heavier shrinkage than that of the range cattle for the same length of time, but when the weight of the animals is considered the percentage of shrinkage is seen to be about the same, the corn-fed steers in transit less than 24 hours shrinking 3.91 per cent as compared with 4.11 per cent for the steers in transit from 24 to 36 hours. This shrinkage was greater than that of the silage-fed steers, but much smaller than for the pulp-fed cattle.

The cattle fed on cottonseed hulls and meal shrank very uniformly, and the gross shrinkage was not large; it was, in fact, not as large as that of either pulp or silage fed cattle. However, all of these cattle arrived at market when snow and ice were everywhere in evidence, and the fill taken in every case was small, so that the net shrinkage was comparatively high.

Cattle shipped in "feed and water" cars do not seem to shrink any more than cattle handled by the common method of unloading to feed in transit, but they do not look as well at market, since they oftentimes have a drawn appearance. This is only natural, as these cars are usually loaded the same as ordinary cars, and the cattle can not lie down to rest.

The shrinkage in transit may be increased by sudden changes of temperature, or by cold rains or snow.

The fill at market varies greatly with different cattle, or with various shipments of the same class of cattle when weather conditions are not the same. The fill depends to a large extent upon the time of arrival. If cattle arrive about four to six hours before they are offered for sale they will usually take a good fill. They may take a good fill, however, and then be held until so late in the day before being sold that they will lose most of it. This is especially true with range cattle, as they are usually nervous and do not eat much in the daytime, while crowds of people are about.

Cattle that arrive the afternoon before being sold usually take a good fill if the weather is favorable and they are given the same kind of feed to which they have been accustomed.

When cattle have undergone a long journey to market requiring from 60 to 100 hours, the character of the accommodations at the unloading station was found to affect the shrinkage of the animals. Where the pens were sheltered, well drained, and located in a quiet place the cattle took a nice fill and a good rest, and the shrinkage was smaller than when they were unloaded under less favorable conditions.

SUMMARY OF CONCLUSIONS.

The three years' work may be briefly summarized as follows:

1. The shrinkage of cattle in transit depends very materially upon:

(*a*) The conditions existing at the time of shipping and upon the treatment received during the drive to the loading pens.

(*b*) The length of time the cattle were held without feed and water before being loaded.

(*c*) The nature of the fill which the cattle had before loading. If it was of succulent grass, beet pulp, or silage, a great loss in weight was experienced.

(*d*) The weather conditions at the time of loading and while in transit.

(*e*) The character of the run to market. Slow, rough runs naturally caused a greater shrinkage.

(*f*) The kind of treatment they received at unloading stations.

(*g*) The time of arrival at market. If they arrived just before being sold, the fill was small. Cattle that were shipped a long dis-

tance and arrived at market during the night usually did not fill well. If they arrived the afternoon before or about daylight of the sale day, they generally took a good fill.

(*h*) The climatic conditions at the market.

2. An exceedingly large fill at market is not desired, as it will detract from the selling price.

3. The shrinkage on calves may seem small, but under normal conditions it holds about the same proportion to their weight as is found with grown cattle.

4. The difference between the shrinkage of cows and steers is not as great as is ordinarily supposed. Steers will usually shrink somewhat less than cows of the same weight.

5. The shrinkage during the first 24 hours is greater proportionately than for any succeeding period of the same duration.

6. The shrinkage of cattle was found to vary in direct proportion to their live weight when conditions were the same and all other factors were equal.

7. The shrinkage of range cattle in transit over 70 hours during a normal year is from 5 to 6 per cent of their live weight. If they are in transit 36 hours or less the shrinkage will range from 3 to 4 per cent of their live weight.

8. The shrinkage of fed cattle does not differ greatly from that of range cattle for equal periods of time. It varied from about 3 per cent with all of the silage-fed cattle and 4.2 per cent with the corn-fed cattle, when both classes of these animals were in transit for less than 36 hours, to 5.4 per cent for the pulp-fed cattle which were in transit from 60 to 120 hours.

9. Cattle fed on silage have a large gross shrinkage but usually fill so well at market that the net shrinkage is small.

10. Pulp-fed cattle shrink more in transit than any other class of cattle, and also present a greater net shrinkage.

11. The shrinkage on cattle is proportionately smaller for each 12 hours they are in transit after the first 24-hour period is passed. This is shown very clearly in Table 29, which presents a general summary of the work.

12. For a long journey the common method of unloading for feed, water, and rest is to be preferred to the use of "feed and water" cars.

13. Cattle should be weighed before being loaded wherever practicable, since a comparison of this weight with the sale weight will show the net shrinkage. Moreover this weight at point of origin may be of material benefit to the shipper in case of a wreck or a very poor run to market.

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